

Safety Study Guidelines

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Preface

The Safety Study Guidelines are for use by ODOT personnel, consultants and local jurisdictions conducting safety engineering studies, preparing reports, and requesting funding. The safety engineering study is an analysis of roadway and traffic related data to determine the contributing factors to an identified crash pattern at an intersection or highway section. The safety engineering study also identifies potential alternative countermeasure(s) meant to reduce crash frequency or severity at the studies site.

The guidelines are intended to establish a uniform format for safety engineering studies throughout the Department which will provide direction for complete safety engineering reports, thus expediting review and analysis. This document is intended to supplement the official Highway Safety Improvement Program (HSIP) Guidance by providing additional details for completing Safety Studies as part of applying for HSIP Funding.

For information regarding the process to obtain funding through the HSIP Program, see the HSIP Procedures Manual maintained by the Office of Systems Planning and Program Management.

Introduction

1.1 History

The American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual, 1st Edition, published in 2010 (HSM) represented the culmination of 10 years of research and development by an international team of safety experts, academics, and practitioners. The manual presents the best available state of the practice in safety analysis, and provides quantitative ways to measure and make safety decisions relating to estimating safety performance. It is a toolbox that provides different analysis approaches, and methods and performance measures, to support decisions in the project development and road management processes. The HSM is intended for use by professionals charged with planning, design, construction, operations, and maintenance of a road or highway system. In effect, use of the HSM will help a state DOT accomplish what its customers and stakeholders expect, which is providing the highest level of safety performance for the financial and other resources provided to the DOT.

The new Highway Safety Manual (HSM) injects quantifiable safety evaluations into roadway planning, design, operations, and maintenance decisions. State, county, metropolitan planning organization and local level safety practitioners can use the HSM tools to perform safety analysis. These new tools allow safety to be compared to other performance measures like traffic operations, environmental impacts and construction costs by calculating the change in crash frequency as a function of the cross-sectional features of different alternatives.

While many of the steps in the safety study development process documented in these guidelines will seem similar to how studies have been prepared historically, changes have been made to the calculation methods required to complete safety study analysis. Completing a safety study still relies on engineering judgment to select the best, lowest cost countermeasures to address the crash pattern at the site. However, to reflect the new procedures and available tools of the Highway Safety Manual, these guidelines have been revised. The changes in crash analysis methodology will bring ODOT Safety Study analysis methods current with the state of practice in Highway Safety through use of the HSM predictive methods.

These safety study guidelines reflect standard procedures which have been developed to provide an understanding of what a safety study is and when and why a safety study needs to be completed. To aid in the transition to the new study methodologies ODOT will provide training opportunities on an ongoing basis available to external as well as internal safety practitioners in the form of a Traffic Academy course. Course registration information can be found on the Systems Planning and Program Management Website.

1.2 Using the Safety Study Guidelines

The purpose of these guidelines is to establish a procedure for conducting safety studies and preparing the crash information to show realistic visualizations of the crash data on aerial maps/sketches, as well as establishing a uniform format for ODOT safety study reports. The guidelines contain samples of maps/figures to be used when presenting the data to local officials, ODOT employees and the public for review, input and comments.

The guidelines detailed within this document are intended to establish a uniform format for safety engineering studies throughout the Department and will provide direction for completing safety engineering reports, thus expediting analysis and review.

1.3 Highway Safety Manual Background Information

The American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual, 1st Edition, published in 2010 (HSM) represented the culmination of 10 years of research and development by an international team of safety experts, academics, and practitioners. The manual presents the best available state of practice in safety analysis, and provides quantitative ways to measure and make safety decisions relating to estimating safety performance. It is a toolbox that provides different analysis approaches, and methods and performance measures, to support decisions in the project development and road management processes. The HSM is intended for use by professionals charged with planning, design, construction, operations, and maintenance of a road or highway system. In effect, use of the HSM will help a state DOT accomplish what its customers and stakeholders expect, which is providing the highest level of safety performance for the financial and other resources provided to the DOT.

The HSM injects quantifiable safety evaluations into roadway planning, design, operations, and maintenance decisions. State, county, metropolitan planning organizations and local level safety practitioners can use the HSM tools to perform safety analysis. These new tools allow safety to be compared to other performance measures like traffic operations, environmental impacts and construction costs by calculating the change in crash frequency as a function of the roadway characteristics of different alternatives.

Part C provides a predictive method for estimating expected average crash frequency of a network, facility, or individual site, and it introduces the concept of safety performance functions (SPFs).

The chapters in Part C provide the predictive method for segments and intersections for the following facility types:

- Chapter 10 – Rural Two-Lane, Two-Way Roads
- Chapter 11 – Rural Multilane Highways
- Chapter 12 – Urban and Suburban Arterials

(Freeway Chapters are currently under review but the ISATe tool is available for analysis procedures)

Predicting the average crash frequency as a function of traffic volume and roadway characteristics is a new approach that can be readily applied in a variety of ways, including design projects, corridor planning studies, and smaller intersection studies. The approach is applicable for both safety specific studies and as an element of a more traditional transportation study or environmental analysis.

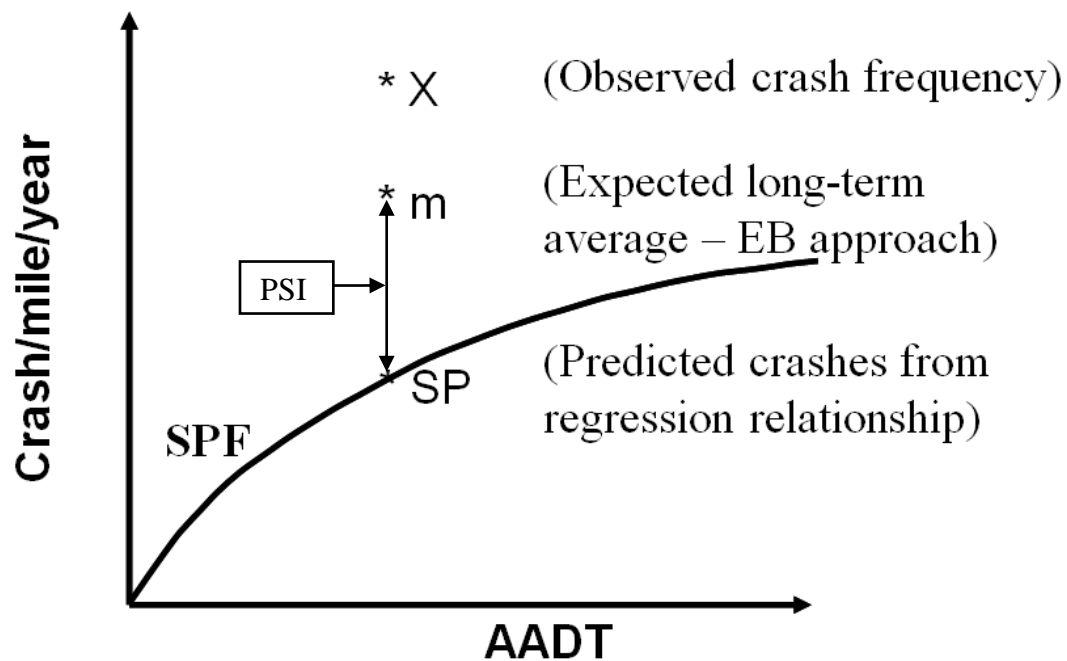
Analysts can use the HSM Part C predictive methods to determine the long-term crash frequency, eliminating the regression to the mean bias. The first step in the process is predicting the number of crashes that should be occurring at a location based on Safety Performance Functions (SPFs) and site characteristic modification factors. With the Ohio calibration factor, the resulting crash frequency would be the predicted crash frequency at the site based on peer sites with similar characteristics. The use of the empirical bayes methodology weights the observed crash frequency with the predicted crash frequency to determine the expected crash frequency. The expected crash frequency is the estimate of long-term average crash frequency of a site, facility, or network under a given set of geometric conditions and traffic volumes (AADT). If the expected crash frequency is greater than the predicted crash frequency, the site is believed to have potential for safety improvement (PSI) or an expected excess average crash frequency.

For more information:

<http://safety.fhwa.dot.gov/hsip/resources/fhwasa09029/sec2.cfm>

The following chart illustrates the above description pictorially:

Observed vs. Long-term Expected Average vs. Predicted



Safety Study Scoring Criteria

2.1 Scoring Criteria

2.1.1 Overview

The scoring criteria aid the multi-disciplinary committee in prioritizing projects for funding. The categories comprise of safety, traffic and economic factors that indicate potential projects for Highway Safety Improvement Program (HISP) funding. Applications should have a positive benefit cost ratio and have a clear relationship between countermeasures and crash patterns.

2.1.2 Existing Conditions Expected Crash Frequency

The estimate of long-term expected average crash frequency of a site, facility, or network under a given set of geometric conditions and traffic volumes (AADT) and is measured in number of crashes per year.

As discussed in the HSM background section, the expected crash frequency is calculated based on Part C Methodology. It is calculated based on a safety performance function to determine the predicted crash frequency. The predicted crash frequency is weighted with the observed crash frequency of the site with empirical bayes methodology. The resulting value is the expected crash frequency or the long-term crash frequency of the project. This methodology removes the regression to the mean bias in the observed crash data to produce a more reliable long-term crash frequency. The predictive calculation process accounts for the non-linear relationship between crashes and AADT.

Refer to the Highway Safety Manual Volume 2, Chapters 10, 11, and 12 for methodology. The Economic Crash Analysis Tool (ECAT), maintained by the Office of Systems Planning and Program Management, conducts this analysis based on user input. The ECAT Tool has been developed to work on both state and locally maintained roadways.

This attribute indicates the concentration of the crash frequency for a specific project.

2.1.3 Ratio of Observed Fatal and Serious Injuries to Observed Total Crashes

This measure determines how many observed fatal or serious injuries occurred at a location in relation to the total number of observed crashes. The total number of fatal and serious injuries is divided by the total number of crashes to create the ratio.

Fatal Injury (K): Any injury that results in death within a 30-day period after the crash occurred.

Serious/Incapacitating Injury (A): Any injury, other than a fatal injury, which prevents the injured person from walking, driving or normally continuing the activities the person was capable of performing before the injury occurred. Often defined as “needing help from the scene.”

$$\text{Ratio} = \frac{\sum K_i + A_i}{N}$$

where,

K = Fatal Injuries

A = Serious Injuries

i = All persons involved in the crash

N = Total Number of Crashes

The numerator is the total number of people involved in the crashes where their injuries resulted in a fatality or a serious injury. To determine the likelihood of similar injuries occurring at the site, this total is divided by the total number of observed crashes that the site has experienced.

This criterion indicates not only the existence of serious injury crashes, but the probability of similar injuries occurring out of the total number of observed crashes.

2.1.4 Percentage of the Potential for Safety Improvement to Total Expected Crashes

This criterion compares the potential for safety improvement (expected excess crash frequency) to the long-term average crash frequency. The potential for safety improvement is a percentage of the expected crash frequency and this percentage identifies how many crashes that are expected to be reduced.

As discussed in the HSM background section, the existing conditions expected crash frequency is calculated based on Part C Methodology. The predicted crash frequency is weighted with the observed crash frequency to calculate the expected crash frequency. If the expected crash frequency is greater than the predicted crash frequency, the site is believed to have the potential for safety improvement (PSI) or expected excess average crash frequency. The PSI frequency is then divided by the expected crash frequency to determine the percentage of crashes that may be reduced.

$$\text{Percentage} = \frac{\text{PSI}}{\text{Expected Crash Frequency}}$$

Refer to the Highway Safety Manual Volume 2, Chapters 10, 11, and 12 for methodology. The Economic Crash Analysis Tool (ECAT), maintained by the Office of Systems Planning and Program Management, conducts this analysis based on user input. The ECAT Tool has been developed to work on any state or locally maintained roadways.

This scoring attribute will not only indicate the potential for safety improvement, but what percentage of the crashes at a site could be reduced.

2.1.5 Relative Severity Index (RSI)

The Relative Severity Index (RSI) represents the relative cost to society of a specific type of crash (head on, rear end, angle crash, etc.). The RSI is the sum of the relative costs per crash divided by the total number of crashes. This scoring attribute identifies the severity potential that a location may have based on the distribution of crash types by different area types.

$$\text{RSI} = \frac{\sum_{i=0}^n N_{\text{Exp},i} \times \text{Crash Type}_i}{N_{\text{Exp},\text{total}}}$$

where,

$N_{\text{Exp},i}$ = Expected crash frequency by crash type

Crash Type_i = Weighting factor by crash type and area type

$N_{\text{Exp},\text{total}}$ = Total expected crash frequency for the project

This scoring attribute utilizes crash type to estimate the potential for serious injuries. Crash types in urban areas result in different severities when compared to the same crash type in a rural area. By comparing the costs of crashes by crash type and area type, the calculation will provide a better understanding of the potential for a serious injury crash.

2.1.6 Equivalent Property Damage Only (EDPO) Index

Each crash is weighted based on the crash severity and the equivalent property damage only crash cost. The EPDO index is calculated by weighting crashes as follows:

- The number of property damage only crashes multiplied by 1.00
- The number of possible/reported injury crashes multiplied by 6.13
- The number of visible injury crashes multiplied by 10.84
- The number of fatal or serious injury crashes multiplied by 90.54

$$\text{EPDO Index} = \frac{\sum_{i=0}^n N_{\text{Exp},i} \times \text{Severity Factor}_i}{N_{\text{Exp},\text{total}}}$$

where,

$N_{\text{Exp},i}$ = Expected crash frequency by crash severity

Severity Factor_i = Weighting factor by crash severity

i = Each crash type

$N_{\text{Exp},\text{total}}$ = Total expected crash frequency for the project

The Human Capital Crash Costs are the costs of each crash by either crash type or severity that includes monetary losses associated with medical care, emergency services, property damage, and lost productivity.

Crash Severity		2012	Number of Crashes	EPDO
Fatal	K	\$1,619,280	1,029	37.93
Disabling Injury	A	\$144,820	7,858	
Evident Injury	B	\$54,470	31,476	6.55
Possible Injury	C	\$36,920	32,752	4.44
PDO	O	\$8,320	213,918	1

This is another severity factor but looks at the expected crash frequency. This takes into account the long-term average crash frequency at the site. This will provide a better picture of the crash severity for the project in the long-term than compared to the “Ratio of Observed Fatal and Serious Injuries to Observed Total Crash” scoring criteria.

2.1.7 Truck Percentage

Truck Annual Average Daily Traffic (TAADT) divided by Total Annual Average Daily Traffic (AADT). This calculation is used to determine what percent of the roadway is being utilized by large commercial vehicles. This component is factored into the scoring to inform the safety review team if there is a significant amount of truck travel at the location. The percentage is calculated by obtaining the Truck Annual Average Daily Traffic (TAADT) and dividing it by the Annual Average Daily Traffic (AADT).

Collisions with large commercial trucks have the potential to increase the severity. Because of this, it is important to improve locations with high percentage of trucks.

Additionally, Ohio has the 4th largest interstate system in the nation. Sixty-eight (68) percent of the freight in the state is carried on the highway system, over 900 million tons annually. With such a strong reliance on shipping on the highway network, we want to reduce crashes on major shipping routes. This will aid in strengthening Ohio’s economy.

2.1.8 Volume to Capacity Ratio

The volume to capacity ratio is a measure of congestion or the amount of traffic on a given roadway in relation to the amount of traffic the roadway was designed to carry.

While congestion is often a good indicator of crashes, the associated crashes do not often result in serious injury crashes. These locations are often very expensive to improve and do not reduce the number of deaths or serious injuries on Ohio's roadways. Therefore, we have reduced the weight this category receives in the scoring process.

2.1.9 Benefit Cost Ratio

The benefit cost ratio identifies the relationship between the safety benefits of a specific countermeasure or set of countermeasures compared to the project cost. The project investment is the cost of the improvement plus cost of maintenance for the life of the improvement. The benefit is the savings based on crash modification factors using the human capital crash costs. Safety Benefits are projected into the future based on projected traffic volume growth. The final benefits are then converted into present values by using a discount rate of four percent (4%) in order to compare to project costs.

Project costs are identified by countermeasure. Depending on the service life of a countermeasure, it may need to be implemented multiple times over the total life cycle of the project. For example, the total service life of the project is 20 years and a single countermeasure has a service life of five (5) years. This would require that the improvement be installed at years 0, 5, 10, and 15 or a total of 4 times. The costs for all four (4) of the installations of the countermeasure are included in the total project cost. This is necessary to continue to observe the safety benefits for a particular countermeasure for the total service life of the project.

$$\text{Ratio} = \frac{B}{C}$$

where,

B = Present Value of Total Safety Benefits

C = Present Value of Total Project Costs

For purposes of scoring, the project costs shall be based on total project cost, not safety funding request. A safety funding request of less than the total project cost will receive points as described in the next section "Safety Request Percentage."

This attribute will help identify projects that are cost effective. When the safety benefits exceed the project costs, the ratio is greater than one (1). A value greater than one (1) is typically required to obtain safety funding.

2.1.10 Safety Request Percentage

This measure identifies other funding sources that are being combined to complete the project. By combining other funding sources, it allows the Highway Safety Improvement Program to make a larger impact around the State. Additionally, it indicates a vested interest in the project at the local level.

$$\text{Percentage} = \frac{S_T}{P_T}$$

where,

S_T = Total amount of safety funding requested

P_T = Total project cost

For scoring, the safety funding requests shall include both current and previous funding requests from the HSIP Program.

While the Ohio Highway Safety Improvement Program is one of the largest programs in the country, we still want to make as many safety improvements around the state as possible. By obtaining matching money from other sources, it allows this opportunity. This has become important in the decision making process of the selection committee; and therefore, points will be awarded for this attribute.

2.2 Safety Study Analysis Resources and Tools

2.2.1 GIS Crash Analysis Tool (GCAT)

ODOT's GIS Crash Analysis Tool (GCAT) is an easy to use tool that provides a convenient way for qualified agencies to search statewide crash data. Once searched, this data can then be downloaded and analyzed using the ODOT CAM Tool (Excel Crash Analysis Module) or Economic Crash Analysis Tool (ECAT). The purpose of GCAT is to provide a convenient highway safety crash analysis tool for ODOT, MPOs and county engineers. The tool includes both state system and local system crash data that is spatially located and unlocated. The tool allows for queries into the crash database to enable download of crash data (located or unlocated) meeting parameters established by the user. For queries of located crashes the GIS Crash Analysis Tool uses GIS (Geographic Information Systems) to produce data that is spatially located (with valid latitude/longitude).



While the crash data provided by GCAT is not official, it has been provided by the Ohio Department of Public Safety and modified by ODOT for use in engineering and analysis such as that performed to complete Safety Studies. Original crash data reports can be obtained from the law enforcement agency handling the crash or the Department of Public Safety's Ohio Traffic Safety Office Crash Data site.

2.2.2 Crash Analysis Module (CAM) Tool

The CAM tool is a useful resource when preparing safety studies. Crash summaries, graphs, and charts can be created that assist with diagnosis safety issues and defining safety issues through crash statistics. Users are also able to create simple collision diagrams through the tool. The ODOT Crash Analysis Module (CAM) tool is currently the recommended tool used by Local Public Agencies in their identification and evaluation of safety issues within their communities and in preparation of safety studies for Ohio roadway facilities not included in the state system databases. ODOT is in the process of incorporating all Ohio roads into their databases will continue to work with local public agencies to update data and roadway inventory systems with the intent of transition to the ECAT for use in safety study analysis for all Ohio roadways. These tools will continue to be made available for use in evaluating proposed safety countermeasures on the local system until such time as ODOT has determined is appropriate.

ODOT has updated the Crash Analysis Module (CAM) Tool Rate of Return (ROR) Tool as of August 2012 to incorporate Crash Modification Factors (CMF) / Crash Reduction Factors (CRF) from the HSM Parts C and Part D.

2.2.3 Transportation Information Mapping System (TIMS)

ODOT's Transportation Information Mapping System (TIMS) is a web-mapping portal where users can query information about Ohio's transportation system, create maps, and share information. TIMS is a multi-functional application available for use by the public and ODOT employees. The intent of TIMS is to provide employees and public easy access to data about Ohio's transportation system.

Data/information in TIMS includes the following:

- **Projects** – includes awarded projects with committed funds.
- **Assets** – includes data features along or related to the roadway network. Included are pavement conditions, bridges, culverts, outfalls, airports, railways and more.
- **Road Inventory** – contains information regarding physical and administrative data related to the roadway network that are either maintained by or are of special interest to ODOT. This data consists of roadway attributes, covering roadway classification, ownership, physical conditions, functional classification, lanes, roadway surface, highway performance monitoring information and more.
- **Safety** – contains information about crashes that can be located on public roads in Ohio. The data includes information pertaining to the crashes collected by officers such as time of day, weather condition, light conditions, and unit details as well as ODOT generated fields such as crash type. This information is currently only available only to authorized ODOT users at this time. Other users should refer to the GCAT tool for information/queries of crash data.
- **Traffic Counts** – includes annual daily traffic (AADT) and other traffic characteristics available by road segment for the State System (Interstates, US Highways, and State Routes) and selected local roadways. Traffic count station information is also available.

TIMS provides transportation employees, transportation stakeholders and the general public a central access point for viewing, distributing, and analyzing Ohio's transportation data through web mapping tools. The application includes such features as emailing, custom printing, bookmarking, photo imaging, uploading files, and exporting data and information in tabular or graphical form. This application allows the casual user who is not a GIS expert to produce high-quality maps quickly with access to numerous data sets. More information about TIMS can be found at the following location:

<http://tims.dot.state.oh.us/tims/TIMS/>

2.2.4 Economic Crash Analysis Tool (ECAT)

During 2009 and 2010, Dr. Karen Dixon, Principal Investigator of NCHRP 17-38, developed three spreadsheets in a volunteer effort to support training efforts on the first edition of the HSM. These Highway Safety Manual (HSM) predictive analysis spreadsheet tools represent updates to these three spreadsheets. The update was funded through a partnership between the Alabama Department of Transportation and Virginia Department of Transportation. These agencies released these tools for use by other individuals and agencies to support the implementation of the HSM across the nation.



The Ohio Department of Transportation (ODOT) reviewed the previous spreadsheets for their operation and calculation methodology. Based on the needs of ODOT, a single spreadsheet was created to complete the HSM calculations. The Economic Crash Analysis Tool (ECAT) has the ability to calculate predicted crash frequencies, complete Empirical Bayes calculations, predict crash frequencies for proposed conditions, conduct alternatives analyses, and complete a benefit-cost analysis. The ECAT is the preferred method of safety study analysis and required for all safety studies completed for any locations on the state highway system. The current file is available for users to download from the Office of Systems Planning and Program Management, Highway Safety Manual Data Analysis Tools webpage:

http://www.dot.state.oh.us/Divisions/Planning/SPPM/SystemsPlanning/Pages/HSM_DataAnalysis.aspx

This tool will be used as the scoring method for Safety Studies for state facilities beginning with the April 2014 funding round. Future enhancements and updates to the tool will be posted with

release notes documenting any future changes at this location. When starting a new project please return to this website to obtain the latest version. Comments or questions regarding the use of the tool can be directed to Derek Troyer (derek.troyer@dot.state.oh.us), ODOT Office of Systems Planning and Program Management. Help files for the ECAT tool are also posted on the Highway Safety Manual Data Analysis Tools webpage.

2.2.5 Interchange Safety and Analysis Tool, enhanced (ISATe)

The Interchange Safety Analysis Tool (ISATe) was developed under a National Cooperative Highway Research Program (NCHRP) project, NCHRP Project 17-45 by the Texas Transportation Institute (TTI); and CH2M-Hill. The project produced a methodology and supporting documentation for predicting the frequency and severity of crashes on freeways and interchanges, with the ultimate goal being inclusion in the AASHTO HSM. The ISATe models crashes using the same basic methodology as in Part C of the HSM, which currently covers 2-lane rural highways, multilane rural highways and urban arterials.

The ISATe represents the creation of a new method of safety analysis for freeway and interchange systems. ISATe predicts crash frequencies for any given traffic volume (AADT) in a disaggregated manner with separate models for single vehicle and multivehicle crashes. The methodology predicts crashes by crash location, i.e., mainline segment, ramp terminal, and ramp proper. Input to the tool includes both geometric and operational characteristics of the roadway and ramp facilities. ISATe also enables modeling of ramp terminal crossroad intersections based on number and arrangement of lanes and type of traffic control.

The analytical methods for ramp terminal intersections are very similar to the methods for intersections on the roadway types presented in Chapters 10, 11, and 12 of the HSM. As such, analysis for ramp terminal intersections has been incorporated into the ECAT tool for use in preparing safety studies. ODOT is currently evaluating the feasibility of incorporating all analysis methods, including freeway mainline and ramp segments into the tool. In the interim, freeway mainline and ramp segments should be evaluated utilizing the most current version of the ISATe tool available. The tool, including user guide can be found at the following location:

<http://www.highwaysafetymanual.org/Pages/support.aspx>

Comments or questions regarding the use of the tool and for information on conducting safety study analysis for freeways or ramp segments should be directed to the appropriate District Safety coordinator or Safety Program staff.

2.2.6 FHWA Crash Modification Factors Clearinghouse

Traffic Engineers have historically had a “tool box” of strategies that could be deployed to address safety concerns. Recent research efforts have subjected a number of safety measures to a comprehensive package of comparative and before vs. after analyses and rigorous statistical tests. The Highway Safety Manual Part D presents information regarding the effects of various highway safety treatments, or countermeasures in the form of Crash Modification Factors (CMFs) and Crash Reduction Factors (CRFs). These CMFs/CRFs can be applied to the predicted or expected estimated crash performance to estimate how effective the countermeasure or set of countermeasure will be in reducing crashes at a location.

The Federal Highway Administration has published the most comprehensive set of crash modification factors – “Crash Modification Factors Clearinghouse.” The Crash Modification Factors Clearinghouse houses a Web-based database of CMFs/CRFs along with supporting documentation to help transportation engineers identify the most appropriate countermeasure for their safety needs. The Crash Modification Factors Clearinghouse is one of the many tools and resources available to help transportation professionals make safety decisions. The Highway Safety Manual (HSM) provides practitioners with the best factual information and tools to

facilitate roadway design and operational decisions based on explicit consideration of their safety consequences. One of these tools is the inclusion of crash modification factors, which can be used to support an agency's roadway safety management process or as input to the safety prediction methods.

While the HSM provides only the best available research-based CMFs, the CMF Clearinghouse is a comprehensive listing of available CMFs regardless of inclusion in the HSM. Crash modification factors and/or reduction factors (CRFs) are provided for a broad range of intersection treatments, roadway departure strategies, and pedestrian amenities. The CMF Clearinghouse includes all of the CMFs listed in the HSM as well as additional CMFs that have been developed independent of the HSM. The Crash Modification Clearinghouse also serves as a repository for CMFs developed from research compiled or performed since the publication of the most current version of the HSM. These CMFs may be included in future editions of the HSM. Using this site, you can search to find CMFs or submit your own CMFs to be included in the clearinghouse.

More information about the FHWA Crash Modification Clearinghouse can be found at the following location:

<http://www.cmfclearinghouse.org/>

Use of the Clearinghouse in ODOT Safety Study Analysis

ODOT's tools currently reference CMFs contained in the HSM Parts C and D. ODOT also periodically reviews the Clearinghouse for new or more current CMFs to include in their evaluation processes. CMFs deemed appropriate for use in ODOT safety study analysis are included in the Safety Analysis tools and are updated periodically as new or more current CMFs are identified. However, it is possible over the course of developing safety studies that CMFs may be required for conditions that have not yet been incorporated into these tools. ODOT permits and recommends the use of the National CMF clearinghouse as a resource in these situations.

The CMF Clearinghouse review process rates the CMF according to five categories - study design, sample size, standard error, potential biases, and data source - and judges the CMF according to its performance in each category. It assigns a star rating (one through five) based on the cumulative performance in the five categories. When it is determined to be appropriate to use the CMF Clearinghouse for an ODOT Safety Study, ODOT recommends that attention be paid to assessing the appropriateness of each proposed CMF or CRF to the condition being studied. These CMFs and CRFs are a useful guide, but it remains necessary to apply engineering judgment and to consider site-specific environmental, traffic volume, traffic mix, geometric conditions, and operational conditions that will affect the actual safety impact of any countermeasure. ODOT will accept the proposed use of any CMF with a Star Quality Rating of less than 3 only when the application of the countermeasure is in a manner that closely aligns with the study which it was developed. Concerns with the use of a CMF should be discussed with the district safety coordinator or Safety Program staff.

2.2.7 ODOT Historical Crash Modification / Reduction Factors

In September 2005, research was completed to compile a list of crash modification factors. The research report can be obtained here:

<http://www.dot.state.oh.us/Divisions/Planning/SPR/Research/reportsandplans/Reports/2005/Safety/14801-FR.pdf>

There are 12 countermeasures identified by this study that are included in the CMF Clearinghouse. The remainder of the research report summarized other countermeasure modification factors from around the country. Since the Ohio-specific research results are

included in the CMF Clearinghouse, we will no longer be accepting CMF shown if Figure 1 following the April 2014 HSIP Application Cycle without Central Office Safety Staff Approval. Most of the countermeasures are vague and do not indicate the true intention of the improvement. Also, there are several instances where the methodologies outlined in the Highway Safety Manual that supersedes the research included in Figure 1.

Figure 1: Estimates of Countermeasure Effectiveness Reduction Factors

Estimates of Countermeasure Effectiveness Reduction (CRF) Factors

(September 1997, Revised July 2007)

ID	Description	All	PDO	INJ/FAT	Night	Wet	Pedestrian	Left	Right	Angle	Rear	Head	Side	Fixed	Ran
1	1 Upgrade pavement markings - general	0.1													
2	2 Install raised pavement markers, locations & sections	0.09													
3	3 Install plastic pavement markings	0.1													
4	4 De-slick pavement - sections [except wet pavement crashes]	0.2				0.5									
5	5 Resurface - rural sections - 2 lane	0.12		0.21											
6	5a Resurface - rural sections > 2 lane	0.44		0.59											
7	5b Resurface - urban section > 2 lane	0.42		0.46											
8	6 Upgrade signs - general	0.05													
9	7 Lane use signs - overhead										0.1		0.2		
10	8 Warning signs at intersection - rural	0.2		0.25											
11	9 Warning signs on section - rural 2 lane	0.36		0.32											
12	9a Warning signs on section - rural > 2 lane	0.18		0.03											
13	57 Install/improve warning signs on rural curves [curve crashes only]	0.2													
14	30 Install warning sign-mounted flasher	0.3													
15	31 Install PTSWF sign/flasher [for approach speeds > 45 mph]										0.6				
16	58 Install/improve warning signs on sections - rural 2 lane	0.36		0.32											
17	58a Install/improve warning signs on sections - rural > 2 lane	0.18		0.03											
18	59 Install/improve warning signs on sections - urban 2 lane	0.14		0.14											
19	59a Install/improve warning signs on sections - urban > 2 lane	0.26		0.2											
20	60 Install delineators at curve - rural [Curve crashes only]	0.16													
21	13 Install concrete median barrier [median and cross-median crashes only]			0.61											
22	14 Install painted median	0.12													
23	15 Install two-way left turn lane	0.083		0.2											
24	41 Flatten vertical curve	0.2		0.51											
25	16 Install left turn bay & extra pavement without signal							0.2			0.2				
26	17 Install left turn bay & extra pavement with signal							0.2			0.2				
27	37 Widen roadway, rural section, no additional lanes	0.38		0.3											
28	38 Widen roadway, rural section, including additional lanes	0.38		0.3											
29	39 Widen for left turn lane, including resurfacing							0.2			0.2		0.2		
30	40 Widen for right turn lane, including resurfacing							0.2			0.2		0.2		
31	42 Stabilize berms - rural section	0.38		0.3											
32	20 Upgrade existing flasher	0.2													
33	21 Install flasher	0.5													
34	22 Upgrade existing signal - general	0.2													
35	23 Reconstruct existing signal - major	0.27													
36	24 Install traffic signal - all types							0.1	0.1	0.8	-0.1		0.1		
37	25 Revise signal timing	0.1													
38	26 Add pedestrian heads						0.5								
39	27 Add left turn phase with new left turn lane							0.4			0.2				
40	28 Add left turn phase with existing left turn lane							0.3			0.1				
41	29 Add left turn phase without left turn lane							0.2							
42	32 Install optically programmed heads							0.1		0.1	0.1	0.2			
43	33 Remove existing, unwarranted signal														
44	61 Provide signal interconnection														
45	34 Install intersection lighting			0.75											
46	35 Install section lighting			0.5											
47	36 Upgrade existing lighting			0.5											
48	43 Replace culvert													0.6	
49	44 Replace bridge													0.62	
50	45 Widen bridge													0.43	
51	46 Widen culvert													0.25	
52	62 Install guard rail at bridge end [injury-fatal crashes only]													0.2	
53	49 Install guard rail [injury-fatal crashes only]													0.2	0.2
54	63 Improve guard rail [injury-fatal crashes only]													0.2	
55	50 Remove or relocate fixed object to a safe distance from the roadway	0.38		0.38											
56	64 Make utility pole breakaway [Utility pole fatal crashes only]													0.3	
57	65 Relocate utility pole 3 0' from edge of pavement [Utility pole fatal crashes only]													0.32	
58	66 Remove utility pole [Utility pole fatal crashes only]													0.38	
59	67 Remove tree [Tree crashes only]													0.25	
60	68 Make sign support breakaway - all sizes [Sign injury-fatal crashes only]													0.24	
61	69 Install auto. prot. device at R/R grade crossing [Train-vehicle crashes only]	0.28													
62	48 Install impact attenuator device [injury-fatal crashes only]													0.5	
63	47 Eliminate fixed objects													1	
64	55 Improve horizontal alignment - rural section	0.4													
65	70 Reconstruct curves on rural section - 2 lane [Curve crashes only]	0.88													
66	10 Eliminate parking														
67	11 Speed zone														
68	12 Prohibit turn	0.4													
69	18 Close median opening														
70	19 Relocate driveway entrance							0.1	0.1	0.1	0.2	0.2			
71	51 Relocate intersection	0.25													
72	52 Increase cross corner sight distance									0.5					
73	71 Prohibit right-turn-on-red								0.2						
74	53 Install rumble strips														
75	54 Provide proper super-elevation on curve - rural [curve crashes only]	0.5													

The Safety Study Process

3.1 What is a Safety Study?

Highway safety issues (and how to mitigate them) are an important consideration for the Department and the communities it serves. ODOT has one of the largest safety programs in the country. The department dedicates about \$102 million annually for engineering improvements at high-crash or severe-crash locations across the state. This funding can be used by ODOT District Offices or local governments to improve safety on any public roadway. A properly developed highway safety study can provide the factual basis for good decision making and facilitate the timely implementation of necessary improvements.

Specifically, a highway safety study should document the following:

- A method to provide an organized approach to the identification, analysis and mitigation of crash patterns and frequency at highway safety priority locations.
- A systematic approach to evaluate contributing factors to crashes and identify strategies for improvement with the greatest potential to benefit safety.
- A method to estimate the effectiveness of our proposed countermeasure(s).
- If applying for safety funds, a means to justify the proposed countermeasures and project.

3.2 Safety Study Initiation

The safety study process is typically initiated by an ODOT district, MPO or Local government in response to the need to study and address a priority crash location. The first step to any safety study involves a scoping/project kick-off meeting with the District Safety Review Team (DSRT) to define study area and scope. The consultant (or LPA, in the case of Locally-Sponsored Safety Studies & Funding Applications) should come prepared to discuss the study/project purpose and need in detail and, if appropriate, present a recommended study area and scope to the DSRT/District Safety Coordinator.

Requests for crash data or other traffic data (such as traffic volumes) should be prepared in draft form for review during the meeting. The District Safety Coordinator/DSRT and the consultant (or LPA) will discuss and agree upon the time frame for which the crash data will be evaluated for the study area or project. However, in general this time frame will typically consist of the most recent and available 3-year calendar period.

The level of detail and determination of whether a full or abbreviated study is required will be determined at the scoping/kick-off meeting. The higher the complexity and cost to address the issues, the more information will be needed. Where projects are expected to result in a Minor PDP project, multi-disciplinary staff should be included at the scoping/kick-off meeting. The consultant and/or LPA should coordinate with the District Safety Coordinator or District Safety Review Team in advance of the meeting to determine the appropriate staff for attendance. The District Safety Coordinator shall be responsible for inviting ODOT staff and coordinating the schedule of the meeting so that necessary staff can attend.

3.3 Safety Study Process

The ODOT safety study process consists of five steps. Figure 1 summarizes the steps and presents the relationship each of these steps has to the others within the Safety Study process. As shown, the process is intended to be iterative, with steps 2 through 4 repeated as necessary to facilitate the identification and evaluation of countermeasures that best address the particular safety needs of the site/project.

Step 1: Collect Data and Diagnose

Crash Patterns - The activities included in this step provide an understanding of crash patterns, past studies and physical characteristics of the study site or project prior to identification of potential countermeasures. As part of this step the consultant and/or LPA should review historical studies and reports, existing condition data, and crash data and prepare necessary documentation including **collision diagrams** and physical **condition diagrams** in order to inform the site diagnosis and aid in identification of potential countermeasures. The GCAT and TIMS tools can be used to query crash data and roadway inventory data for the site. A field review should be performed to supplement the data and identify and/or confirm crash patterns and potential contributing factors. Information such as the presence of skid marks on pavement, damaged roadside objects such as guardrail, posts, delineation, utility poles, bushes, or trees, and any other evidence of potential safety issues (tire tracks, wearing of roadway/shoulder material, vehicle debris) within the study area should be photographed and documented in the safety study narrative.

It is important that the data collection include consideration of the various HSM site subtypes so that appropriate data can be collected from field visits. Data collection should be performed based on segmentation as defined by the Highway Safety Manual methods. Estimation of the potential for safety improvement (Step 2) requires that analysis be performed utilizing predictive models that estimate the frequency of crashes for a site which has been divided into homogeneous segments and intersections. A homogeneous roadway segment is a section of continuous traveled way that provides two-way operation of traffic, that is not interrupted by and intersection, and consist of homogeneous geometric and traffic control features. Figures 2 and 3 summarize the various data elements that should be collected during the field review by homogeneous segment and intersection. General information on the segmentation of sites can be found in the HSM Part C Introduction, as well as for the individual site types of Rural Two-way, Rural Multilane, and Urban/Suburban Arterials in HSM Chapters 10, 11, and 12, respectively. While the HSM does not specify a minimum length for a homogenous segment, for the purposes ODOT Safety Study analysis, the minimum length of homogenous segment to be used for estimating the potential for safety improvement at a site is 0.10 mile. Segment lengths of less than 0.10 mile may be considered in special circumstances, but only with advanced approval by ODOT.

Step 2: Identify Potential for Site Safety Improvements and Possible Countermeasures – Once the necessary roadway and crash data has been collected and inventoried an analysis should be performed using HSM methods or the ECAT tool to determine the potential for Site Safety Improvements that exists within the study area. This process involves calculating the predicted

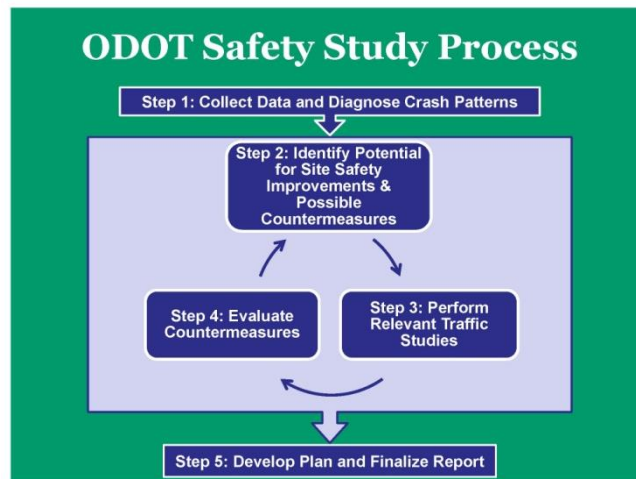


Figure 1a: ODOT Safety Study Process

Figure 2: Segment Data Requirements

Length of segment, L (mi)

AADT (veh/day)

Lane width (ft)

Shoulder width (ft)

Shoulder type

Median width (ft)

Side Slopes

Length of horizontal curve (mi)

Radius of curvature (ft)

Spiral transition curve (present/not present)

Superelevation variance (ft/ft)

Grade (%)

Driveway density (driveways/mile)

Centerline rumble strips (present/not present)

Passing lanes [present (1 lane) /present (2 lane) / not present]]

Two-way left-turn lane (present/not present)

Roadside hazard rating (1-7 scale)

Segment lighting (present/not present)

Auto speed enforcement (present/not present)

Roadway type (divided / undivided)

Auto speed enforcement (present / not present)

Major commercial driveways (number)

Minor commercial driveways (number)

Major industrial / institutional driveways (number)

Minor industrial / institutional driveways (number)

Major residential driveways (number)

Minor residential driveways (number)

Other driveways (number)

Speed Category

Roadside fixed object density (fixed objects / mi)

Offset to roadside fixed objects (ft) [If greater than 30 or Not Present, input 30]

***Items noted in bold italics have typically not been collected under previous processes. Information on these elements can be found in the respective HSM Chapter for the roadway section type under study.**

Figure 3: Intersection Data Requirements

Intersection type (3ST, 4ST, 3SG, 4SG)

AADT major (veh/day)

AADT minor (veh/day)

Intersection skew angle (degrees)

Intersection lighting (present/not present)

Number of approaches with left-turn lanes

Number of approaches with right-turn lanes

Number of approaches with left-turn signal phasing

Type of left-turn signal phasing

Number of approaches with right-turn-on-red prohibited [for 3SG, use maximum value of 3]

Intersection red light cameras (present/not present)

Sum of all pedestrian crossing volumes (PedVol) -- Signalized intersections only

Maximum number of lanes crossed by a pedestrian (nlanesx)

Number of bus stops within 300 m (1,000 ft) of the intersection

Schools within 300 m (1,000 ft) of the intersection (present/not present)

Number of alcohol sales establishments within 300 m (1,000 ft) of the intersection

Type of on-street parking (none/parallel/angle)

Proportion of curb length with on-street parking

***Items noted in bold italics have typically not been collected under previous processes. Information on these elements can be found in the respective HSM Chapter for the roadway intersection type under study**

crash frequency for peer sites (similar to the study site) and the expected crash frequency for the actual site considering historical (actual) crash experience utilizing a mathematical modeling process as defined in the HSM. The difference between the predicted and expected crash frequencies as expressed in expected excess crashes is the potential for site safety improvement that could be addressed through the implementation of safety countermeasures. The ECAT tool developed by ODOT's Office of System Planning and Program Management facilitates the completion of this analysis.

Upon determination of the potential for site safety improvement both the predicted and actual crash performance of the site should be reviewed to identify potential safety countermeasures for evaluation and potential implementation at the site. Review of crash data, roadway inventory and supplemental data collected during the field review can aid in identification of safety issues and crash patterns existing at the site. The results of the HSM analysis and comparison of calculated values for crash frequency, severity and type will provide insight into how the site is performing relative to its peers and if there are any notable differences which also can be used to aid in identification of potential countermeasure treatments. Identification of potential countermeasure for evaluation should include consideration of each of the three general categories of contributing factors - Human, Vehicle, and Roadway/Environment and consider how each of these may influence the sequence of events that occurs before, during, and after a crash. For more information on these concepts and for guidance in developing a framework for relating the series of events in a crash to the general categories of crash-contributing factors refer to the HSM, Chapter 3.

The ODOT ECAT tool contains information on potential countermeasures that can be referenced when diagnosing site issues and identifying potential countermeasure for evaluation. Additionally, the HSM Part D, Chapters 13-17 can serve as a resource and should be referenced for additional information on potential countermeasure treatments including insight on the effectiveness of various safety countermeasure or treatments under consideration.

Step 3: Perform Relevant Traffic Studies – To support the evaluation of potential countermeasures recommended for evaluation in Step 2 it may be necessary to collect supplemental data and/or perform additional supplemental studies. Examples of the types of supplemental analyses or studies that may be needed include the following:

- Volume Studies
- Traffic Control Device Studies
- Signal Warrant Analysis
- Signal Timing/Phasing Analysis
- Spot Speed Studies
- Travel Time and Delay Studies
- Roadway/Intersection Capacity Analysis
- Gap Analysis
- Traffic Lane Occupancy Study
- Queue Length Study
- Sight Distance Study
- Skid Resistance Study
- Highway Lighting Study
- Horizontal Curve (Ball Bank) Study
- Turning Path Analysis
- Parking Study
- Bicycle or Pedestrian Study

Resources available to assist in performing these studies include ODOT's Traffic Engineering Manual, the ITE Traffic Engineering Handbook, the ITE Manual of Traffic Engineering Studies, the Ohio Manual of Uniform Traffic Control Devices (OMUTCD), FHWA's Highway Safety Engineering Studies Procedural Guide, and the AASHTO Highway Safety Manual. Consultation with the DSRT/District Safety Coordinator prior to the initiation of any supplemental studies for verification of need, determination of scope, and approval to proceed is required for all ODOT sponsored safety studies and strongly recommended for locally sponsored projects.

Step 4: Evaluate Countermeasures - After Step 2 site diagnosis and countermeasure identification and upon completion of any necessary supplemental traffic studies (Step 3), the HSM analysis methods will again be used to estimate the safety effectiveness and develop an estimate of the relative cost to safety benefit for each proposed countermeasure or combination of countermeasures. Calculations to determine the expected crash frequency for the site/project with the incorporation of the proposed countermeasures are performed similar to calculations performed for the existing condition analysis of the site as described in Step 2.

The final recommended countermeasure or combination of countermeasures should represent a cost effective treatment or combination of treatments that result in the lowering of the expected crash frequency of the site so it approaches or goes below the predicted crash frequency of the existing condition. Both the calculation of the expected crash frequency for the proposed condition and the economic cost to benefit analysis can be accomplished using either the HSM or the ECAT. The amount that crashes can be reduced will be based on the results of the benefit-cost analysis.

When analysis of the proposed countermeasure does not result in a reasonable reduction of crash frequency relative to cost, as reflected by the cost to benefit analysis, it may be necessary to revisit Step 2 site diagnosis and potential countermeasure identification and/or Step 3 supplemental studies to reassess the safety needs and identify other safety improvements for evaluation and repeat the Step 4 evaluation of the new countermeasures. Low cost, short term improvements should always be among the first series of evaluated countermeasures when performing the Step 4 evaluation process.

Step 5: Develop Plan and Finalize Report

Steps 1-4 including recommended countermeasures and treatments should be documented in the form of a safety study report. The format, either full or abbreviated will have been determined during the scoping of the project. Recommendations should be based upon the potential for safety improvement and consider treatments from the full range of safety strategies including engineering, enforcement, driver education and/or other factors. When developing the implementation strategy, the consultant or LPA should consider whether a combination of improvements may be the best plan for addressing a location.

Final plan recommendations should be based on knowledge of the effectiveness of the proposed improvement and considered within the context of the traffic and site conditions. All practical improvements, including do nothing should be identified, considered, and analyzed for safety so that no feasible alternative is overlooked. Solutions of low cost, short term improvements with high benefit to cost values should be given higher priority and should always be considered within the first tier of recommended solutions of any implementation plan.

Formal Safety Study Report Format and Contents

Formal safety studies are performed for a set number of priority list locations annually, sites recommended by the districts, or for projects under Local Public Agency sponsorship. Formal safety studies are performed to justify higher safety funding requests. As mentioned previously, the level of effort should be identified during a project meeting with the district safety review committee or coordinator.

4.1 Table of Contents

Full safety study reports shall have a Table of Contents (see Figure 4).

4.2 Title Page

The report shall have a title page and it should show the District, County, Route, Section, Safety Analyst Number (#), Safety Annual Work Program (SAWP) Year, study completion date, a location map, (see Figures 5a and 5b) and the name of the consultant and/or LPA that prepared the report.

4.3 One Page Project Summary

The report shall have a one page project summary including basic project information and a site map. This one page summary will identify the major crash trends, patterns and recommended solutions and should directly reflect the countermeasure or set of countermeasure that is being presented for safety funding. See Figures 6a and 6b for a sample One Page Project Summary.

4.4 Executive Summary

Every safety study report for a Non-Freeway Location shall include an Executive Summary, which can be used as an overall summary of the report. The Executive Summary should be no longer than 2-3 pages and present a summary of the information documented in detail within the main body of in the report and should generally adhere to the following outline:

Executive Summary Outline

I. Project Background

- History of problems or crashes
- Include previous improvements to mitigate crashes
- Reason for study

II. Project Purpose and Safety Need

- Safety Analyst Priority List & Ranking
- Analyze crashes
- Potential for Safety Improvement

III. Overview of Safety Issues and Possible Causes

- Crash patterns
- Roadway conditions
- Existing traffic control

- Contributing factors
- Traffic volumes

IV. Recommended Countermeasures & Related Costs

- Summarize All that are Applicable
 - Short term countermeasures
 - Medium term countermeasures
 - Long term countermeasures
- Identify Recommended Countermeasure(s) and Implementation Approach
- Summary of Request for Safety Funding – should relate directly to recommended countermeasure(s)

The Executive Summary is intended to provide a summary of the information and conclusions presented in detail later in the document. As such it should be brief and summary in nature and generally be no longer than 2 pages in length, excluding figures.

Figure 4: Full Safety Study Table of ContentsTable of Contents

- I. Title Page
- II. One Page Project Summary
- III. Executive Summary
 - A. Background
 - B. Purpose and Need
 - C. Overview of Possible Causes
 - D. Recommended Countermeasures & Related Costs
- IV. Purpose and Need
- V. Existing Conditions
 - A. Background
 - B. Conditions Diagram
 - C. Physical Condition Write-up
- VI. Crash Data
 - A. Crash Data Summaries
 - B. Collision Diagram(s)
 - C. Crash Graphs and Tables
 - D. Crash Analyses
 - E. Design Evaluation (if applicable)
 - F. Identification of Potential Countermeasures
 - G. Conclusions
- VII. Summary of Supplemental Traffic Studies
- VIII. Proposed Countermeasure Evaluation
- IX. Conclusions
- X. Recommendations & Prioritization
 - A. Countermeasure Recommendations and Implementation Plan
 - B. Proposed Conditions Diagram(s)
- Appendices

Figure 5a: Title Page Example 1



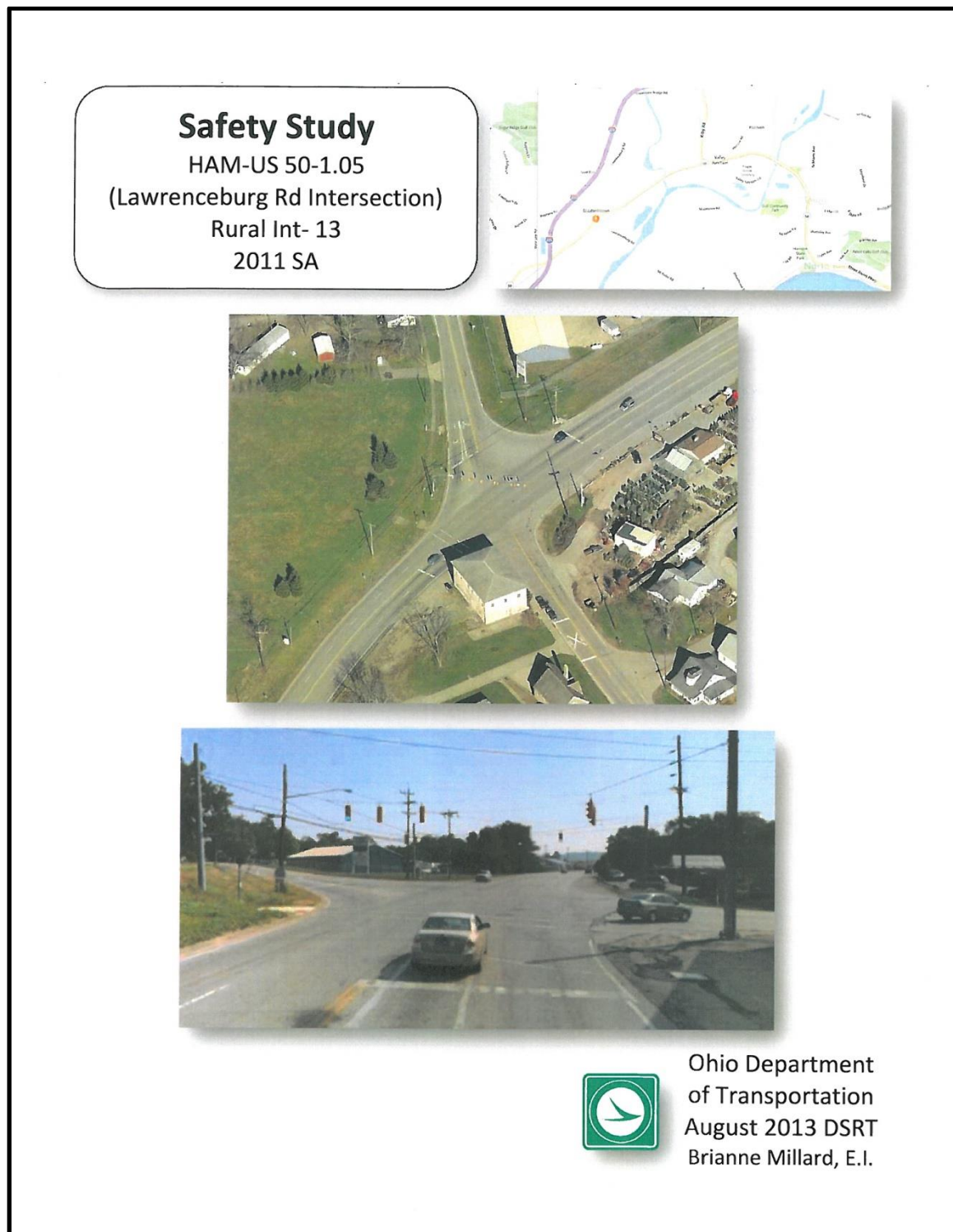
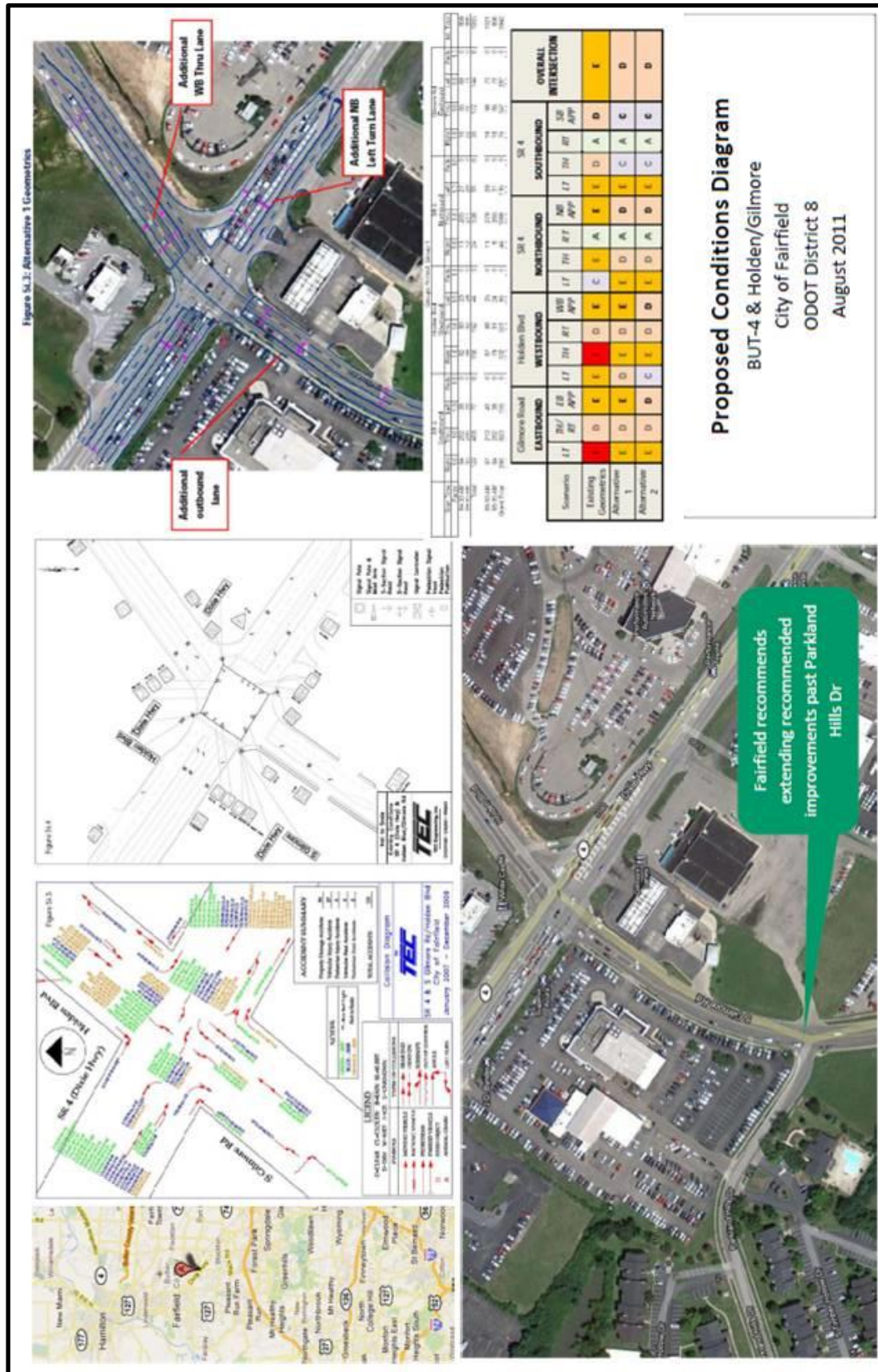
Figure 5b: Title Page Example 2

Figure 6b: One Page Project Summary Example 2



4.5 Purpose and Need Statement

This part of the Safety Study Report is used to identify the location being studied and give the reasons for conducting the safety study. At a minimum the Purpose and Need Statement should identify the Safety Analyst Ranking or local priority, summarize the existing conditions, crash patterns, and crash analysis that support the need for conducting the study, and confirm the potential for site safety improvement as determined through the analysis process described in Step 2 of The Safety Study process.

Example 1

This study analyzes SR 3 at the TR 105 (Plumb Road) intersection. This intersection is ranked #XX in ODOT's 20XX listing of rural intersection locations. The purpose of this report is to study this location and analyze the crashes to determine what, if any, actions can be taken to reduce the high percentage of angle and rear end crashes that have occurred in the study area.

Example 2

The location addressed in this study was identified as HAM-US 50 1.05. The study area is the intersection of US-50 and Lawrenceburg Road, a mile from the Indiana state border. This location was ranked 13th on the safety analyst list of top rural intersections. The purpose of this study is to analyze the crash trends at this location and recommend countermeasures to mitigate any safety or congestion issues.

Example 3

The purpose of this study is to evaluate the existing safety conditions and to identify potential countermeasures at the intersection of SR-64 (log point 0.46) and IR-75 SB exit/entrance ramp in Wood County. This intersection is a priority location for the City of Bowling Green, and has been approved for study by the District 2 DSRT. The current lane configuration leads to long queues which extend beyond the adjacent intersection with very poor lane utilization. Secondary crashes result from this queuing and can be seen as far down as Alumni Drive. Bowling Green State University is in close proximity to this intersection and during special events, the traffic on the southbound off-ramp routinely backs onto the IR-75 mainline creating hazardous speed differentials. Lastly, pedestrian accommodation throughout this corridor is a priority for both the City of Bowling Green and Bowling Green State University.

4.6 Existing Conditions

4.6.1 Background

This section of the report is used to identify the location being studied (County/City/Township, Route, and Section), type of facility (Functional Classification, number and direction of lanes) existing traffic control, history of safety problems or crashes, and reason for the study. If applicable, information summarizing previous or planned improvements to mitigate crashes should be documented.

Example 1

This approximately 1.16 mile section of S.R. 56 is located in Pickaway County. It is part of the rural state highway system under the jurisdiction of District 6 of the Ohio Department of Transportation (ODOT). The section under study, log point 26.44 to 27.60, begins at the intersection of S.R. 159 and S.R. 56 and extends in an easterly direction just beyond and including the Township Road (T.R.) 62 and S.R. 56 intersection. The project limits extend longitudinally 1000 feet along the center line at intersections and 200 feet laterally from the center line along the entire length of the study area. Based on information supplied by District 6, PIC-56-26.92 to 27.41 was ranked #XX on the 2013 Priority List for rural intersections.

Example 2

Main Street (U.S. Route 40) is a six (6) lane asphalt roadway with turn lanes being provided at major intersections. The current posted speed limit for Main Street is 35 mph. According to information obtained from the Ohio Department of Transportation's (ODOT's) website, Main Street is classified as an urban principal arterial. The calculated ADT on Main Street to the east of its intersection with McNaughten Road is approximately 38,000 vehicles per day and the ADT to the west is approximately 46,000. In the study area, Main Street is a straight, flat roadway which has enclosed drainage and concrete curbs on both sides of the roadway. Street lighting exists on the north side of the roadway and the only sidewalk is a short length on the north side of the street, immediately east of McNaughten Road.

McNaughten Road is a two (2) to four (4) lane asphalt roadway in the vicinity of the intersection. The current posted speed limit for McNaughten Road is 35 mph. According to information obtained from ODOT's website, McNaughten Road is classified as an urban minor arterial. The calculated ADT on McNaughten Road to the north of its intersection with Main Street is approximately 16,000 vehicles per day and the ADT to the south is approximately 17,000. In the study area, McNaughten Road is a straight, flat roadway which has enclosed drainage and concrete curbs on both sides of the roadway. Street lighting does not exist along the roadway and some short sections of sidewalk are provided on both sides of the roadway just north of the McNaughten Road intersection.

Example 3

The location under study is the intersection of State Route 164 and State Route 558 located in Columbiana County (District 11). State Route 164 (SR 164) is a two-lane, undivided roadway classified by ODOT as a Rural Minor Collector with a statutory speed limit of 55 miles per hour oriented in the north-south direction. SR 164 is located 1,000 feet west of and runs parallel to State Route 11, a limited access facility. State Route 558, (SR 558) is a two-lane undivided roadway classified by ODOT as a Rural Minor Arterial with a statutory speed limit of 55 miles per hour oriented in an east-west direction. The land use is primarily agricultural with a limited number of placed residential units in the project vicinity.

State Route 164 intersects SR 558 as a two way stop-controlled intersection with stop control for the SR 558 approaches. There are no exclusive turn lanes at the intersection. Current daily traffic volumes on SR 164 range between 1,990 and 2,120 vehicles per day with 4 percent daily truck traffic. Current daily traffic volumes on SR 558 range between 1,240 and 1,550 vehicles per day (5 -6 % trucks).

A review of crash data provided by the Ohio Department of Transportation (ODOT) yielded a total of 26 reported crashes within the intersection influence area (500 feet on each approach) during a 3-year period between 2009 and 2011. The following notable crash types and conditions are present at the SR 164/ SR 558

- Angle: 16 crashes or 61.5 percent
- Fixed Object: 7 crashes or 26.9 percent
- Sideswipe Meeting: 2 crashes or 7.7 percent
- Road condition - Snow: 4 crashes or 15.4 percent

No fatalities were reported at the intersection during the study period.

ODOT currently has plans to modify pavement markings in the spring of 2013 to adjust the stop line locations on the SR 558 approaches to SR 164. The existing stop lines on the stop controlled approaches of SR 558 are positioned 35 feet (eastbound approach) and 28 feet (westbound approach) from the edge line of the intersecting street (SR 164). The position of these stop lines are planned to be moved to a distance of 15 feet from the edge line of SR 164.

4.6.2 Condition Diagram(s)

The condition diagram is a “to scale” drawing of the most important physical conditions of an intersection or section of a roadway. It is used to relate the crash patterns found on the collision diagram with their probable causes to physical features on and near the roadway. It also documents the site conditions that exist. It is often helpful to utilize aerial imagery as the base layer for creation of the existing conditions diagrams. It provides easy points of reference as well as information regarding the development in the project area.

As noted previously, it is important that the data collection include consideration of the various HSM site subtypes so that appropriate data can be collected from field visits. At a minimum, the following items should be included in the Physical Condition Diagram, condition write-up, or documented within one of the appendices in the report. Refer to Figures 2 and 3 for more detail on the specific data elements that are required to complete the analysis required for the safety study.

Roadway Features Required

The following features shall be shown in the drawing or in the related descriptive text:

1. Intersections: Identify by name, type of pavement (if applicable) and width of street.
2. Traffic Control Devices (signs, signals and pavement markings).
3. Section: Identify by county, route and log point in the title block of the drawing.
4. North arrow and match line if more than one page.
5. Pavement Markings: Center Line, No Passing Zones, Auxiliary Markings, Stop Lines, Crosswalks, etc.
6. Signs: All signs within the right-of-way, including non-OMUTCD signs, sign sizes (optional).
7. Pavement and shoulder widths, shoulder types and any surface irregularities.
8. Speed limits.
9. Driveways: Identify type of pavement of drive (concrete, asphalt, grass or gravel), and use (residential or commercial) when applicable.
10. Show Corporation Lines.
11. Curb: Identify type of curb, height, etc. (detail information about the curb is optional).
12. Median: Identify type of median (grass, concrete, asphalt, etc.) and width.
13. Curves: Include approximate radius of curvature.
14. Roadside features: physical object within the right-of way including approximate offset, grades, ditch locations along the roadside, but not behind guardrail.
15. Cross-corner sight distance at intersection or driveway with crashes.
16. Bridges and culverts, if involved in the accident.
17. Legend is required when using symbols on the diagram.
18. Other items that may be contributing factors.

Roadway Features, If Applicable

When applicable to the site (i.e. where site type dictates this data is required for analysis or where a roadway feature appears to be related to or contributing to crash patterns in the area) the following items should also be included:

1. Show evidence of parking (official or unofficial) within the right-of-way, if any.
2. Utility/Strain Poles: location and offset.
3. Guardrail: Include distance from edge of pavement, type of end treatment and height of guardrail (distance and height of guardrail optional).
4. Fire Hydrants: location and offset.
5. Highway lighting: location and offset.
6. Location and widths of drive, street number address (optional): Commercial or residential, any restricted movement.
7. Catch basins (optional).
8. Manholes (optional).
9. Vegetation: If contributing factor to the crash problem.
10. Trees in the right-of-way: Identify by diameter if contributing to crash problem.

All physical condition information should be located by reference to a benchmark that can be identified in the field at any time. A title block identifying the location shall be used consistently in all drawings. While not required, sketch level typical sections offer an effective means to document cross section information, which is needed for each distinct homogenous section (see Section 3.3) in order to complete required crash analysis. See Figure 7 for an example of an existing condition diagram for a roadway section and Figure 8 for an intersection.

4.6.3 Physical Condition Write-up

The physical condition write-up expands upon the information presented in the background section and physical conditions diagram and explains in more detail the type of location, type of roadway, traffic control devices in place, traffic and any operational or geometric conditions unique to the location. This section should also be used to document existing conditions information collected during the field review and highlight details that would not otherwise be *captured in the existing conditions diagram*.

Figure 7: Existing Conditions Diagram – Roadway Section

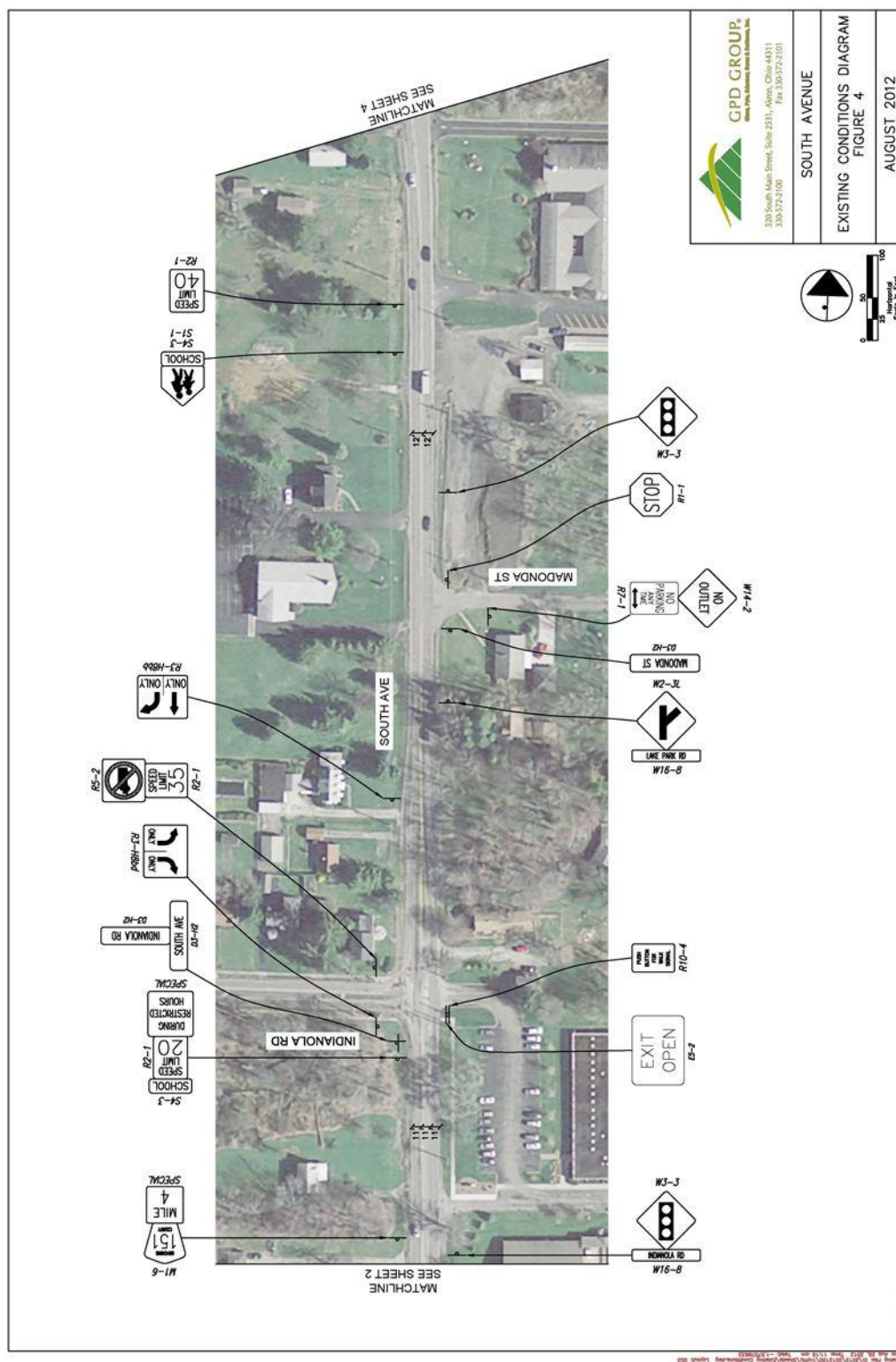


Figure 8: Existing Conditions Diagram - Intersection



Example 1

Based on field observations, the pavement at the intersection appears to be in good condition with minor cracking that has been sealed. The pavement markings also appear to be in good condition except for the stop bars on Plumb Road on either side of SR 3, where they are very faded. The paved shoulder in the southeast corner of the intersection is starting to crumble. Additionally, there are no speed limit signs on SR 3 near this intersection; the closest one is located several miles away. No pedestrians or bicyclists were observed during the field activities, and no 'goat paths' (worn areas alongside the roadway) were observed along the sides of any of the roadways. So there are no indications that pedestrians are walking in the project area with any regularity.

Example 2

US-50 is classified as a rural minor arterial. The posted speed limit through this section is 45 miles per hour. The 2009 reported ADT is 10,580 with 6% trucks. This section of US-50 is 2 lanes in both directions. There are no turn lanes at the intersection on US-50 but southbound Lawrenceburg Road has a right turn lane and a thru-left lane.

There is 1 signal head per lane in all directions. Eastbound traffic has an extra head on an opposite span to drivers coming around the curve to see the signal. The signal heads are in fair condition. There is a flashing signal ahead sign on eastbound 50 and a regular signal ahead sign on westbound 50. Finally, the pavement and pavement markings are in fair condition.

Example 3

S.R. 56 is a rural two-lane roadway. The layout of S.R. 56 within the study area consists of horizontal and vertical curves, residential drives and a commercial drive. The driveways in the study section were counted and their distance from S.R. 159 measured. Standard center line and edge line markings exist throughout the study area. The curves between S.R. 159 and T.R. 62 are marked with warning signs and Advisory Speed Plaques. A number of vehicle types travel this roadway, including semi-trucks, farm equipment and horse-drawn buggies.

The intersection of S.R. 56 and S.R. 159 is a four-way stop with an all-way red intersection flasher. Each leg of the intersection is 21 feet in width from edge line to edge line with a 2-foot paved berm and varying gravel berm beyond the edge of the paved berm. The two State Routes come together to form an approximate 90 degree intersection. Stop lines and Stop Ahead signs are on all four approaches of the intersection. D-1 assemblies and standard route direction and confirmation markers are also on each approach of the intersection.

The intersection of SR 43 and SR 183 is under the control of a NEMA Control Cabinet and monitor, operating a 3 phase signal sequence. The signal is pre-timed with a total cycle length of 92 seconds. The traffic signals are mounted on a span wire that uses two wooden poles for support. There is a minimum of 16 ft. of vertical clearance under the signal heads.

4.6.4 Photos

Include relevant photos taking during the field review that provide insight to or identify and/or confirm crash patterns and potential contributing factors. Photographs taken during Step 1 should document may document existing conditions or evidence of safety issues such as the presence of skid marks on pavement, damaged roadside objects such as guardrail, posts, delineation, utility poles, bushes, or trees, or and any other evidence of potential safety issues (tire tracks, wearing of roadway/shoulder material, vehicle debris) as observed during the field review. No specific requirement exists for the number, frequency, or location of photographs to be taken. Photographic detail should be sufficient to visually document the intended feature or condition. A brief narrative describing the photo location and subject should be included either individually with each picture or listed and summarized in tabular form.

4.6.5 Other Issues and Data

Other relevant data and information are included when such information is essential in garnering support of the study and the countermeasures being recommended. Relevant information may include proposed developments, schools, shopping malls, public concerns/petitions, newspaper articles, and public and law enforcement officer's concerns.

4.7 Crash Data and Analysis

4.7.1 Crash Data Summaries, Graphs and Tables

Crash data helps identify crash patterns which are indicative of possible safety problems. A minimum of three years of the latest crash data shall be used for review of crash data and analysis. In general, crash summaries should include summaries by crash type, severity, contributing factors. In addition to these attributes, select summaries such as environmental conditions, time periods, and driver related information may be provided if it indicates a pattern that a safety countermeasure may address.. Providing all of the standardized charts from the Crash Analysis Module is often not necessary to support the project. Rather, what is included in the Safety Study Report (including Appendices) should be limited to only what is useful or necessary for easy comparison and trend analysis.

The crash analysis procedures include the study and analysis of the crash characteristics of a site based on the historical crash data. The characteristics such as crash type, severity, contributing factors, environmental conditions and time period are analyzed. The detailed analysis of these characteristics is conducted to identify safety problems, contributing factors and will serve to inform the selection of the range of potential countermeasures.

Example 1

From 2010-2012, 24 crashes occurred within the study area. In 2010 there were 10 crashes; in 2011 there were 8 crashes; and in 2012 there were 6 crashes. Of the total crashes, 21% resulted in injury. The most prominent type of crashes was rear end crashes with 58% followed by sideswipe passing crashes with 25%. Approximately 20% of the crashes occurred in wet conditions. Please see Appendix A for the crash analysis and Appendix B for the crash diagram.

Fridays had the highest occurrence of crashes with 42%. The afternoon hours of 2pm and 5pm each had 21% of the crashes. Eastbound drivers were involved with 58% of the crashes.

After reviewing the crash data for this study area, the following observations and trends were compiled:

- *EB sideswipe passing crashes: 4 in 2010, 1 in 2011; 3 from the left lane; 2 from the right lane*
- *EB rear end crashes: 2 in 2010; 1 in 2012; 2 in left lane; 1 in right lane*
- *WB rear end crashes: 2 in 2010; 5 in 2011; 2 in 2012; 6 in left lane; 3 in right lane*
- *There was only 1 left turn crash at the intersection involving a westbound driver turning in front of an eastbound driver who was passing another eastbound left-turning car on the outside*

Example 2

*A total of 18 crashes over the three-year period from 2009-2011 were logged within the study area. Detailed crash data and related graphs are included in **Appendix B**, however, an overview is shown below:*

All Crashes

CRASH YEAR	Number	%
2009	4	53.3%
2010	6	26.7%
2011	8	20.0%
Grand Total	18	100.0%

ROAD CONDITION	Number	%
ROAD - DRY	10	55.6%
ROAD - WET	4	22.2%
ROAD - SNOW	3	16.7%
ROAD CONDITION NOT STATED	1	5.6%
Grand Total	18	100.0%

LIGHT CONDITION	Number	%
DAYLIGHT	14	77.8%
DARK - NO LIGHTS	4	22.2%
Grand Total	18	100.0%

LOCATION	Number	%
INTERSECTION	18	100.0%
Grand Total	18	100.0%

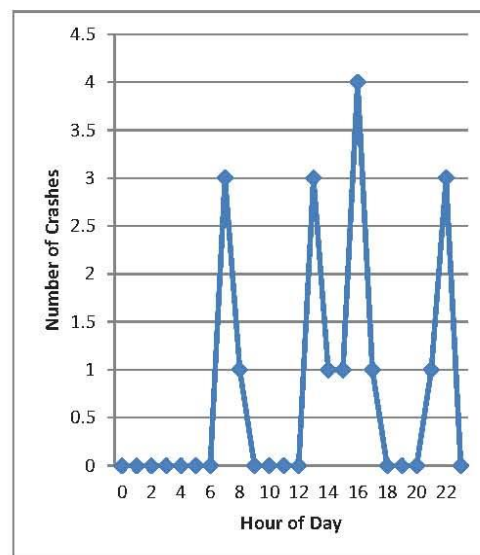
TYPE OF CRASH	Number	%
ANGLE	8	44.4%
REAR END	5	27.8%
LEFT TURN	3	16.7%
SIDESWIPE - MEETING	1	5.6%
HEAD ON	1	5.6%
Grand Total	18	100.0%

HOUR OF DAY	Number	%
7:00	3	16.7%
8:00	1	5.6%
13:00	3	16.7%
14:00	1	5.6%
15:00	1	5.6%
16:00	4	22.2%
17:00	1	5.6%
21:00	1	5.6%
22:00	3	16.70%
Grand Total	18	100.00%

CRASH SEVERITY	Number	%
FATAL CRASH	1	5.6%
INJURY CRASH	10	55.6%
PROPERTY DAMAGE CRASH	7	38.9%
Grand Total	18	100.0%

ROAD CONTOUR	Number	%
STRAIGHT - LEVEL	16	88.9%
STRAIGHT - GRADE	1	5.6%
CURVE - LEVEL	1	5.6%
Grand Total	18	100.0%

CONTRIBUTING FACTOR	Number	%
FAILURE TO YIELD	9	50.0%
FOLLOWING TOO CLOSE	4	22.2%
FAILURE TO CONTROL	2	11.1%
NO DRIVER ERRORS	1	5.6%
RAN STOP SIGN OR YIELD SIGN	1	5.6%
IMPROPER TURNING	1	5.6%
Grand Total	18	100.0%



Crash reports from January 1, 2009 through December 31, 2011 were obtained. During this three-year period, a total of 18 crashes were located within the study limits with a low crash rate of 1.39 crashes per million entering vehicles. **Figure 3** (page 11) shows the collision diagram, which details the locations of these crashes. Almost half of the crashes (44%) are angle crashes, 28% are rear end crashes, and 17% are left turn crashes – all of which resulted from vehicles unsuccessfully crossing this unsignalized intersection; the remaining include sideswipe meeting (1) and head on (1).

For the angle crashes, all were caused by drivers on Plumb Road failing to yield to SR 3 traffic or failing to stop. These crashes include the one fatal crash at the intersection, and all of the remaining angle crashes were injuries, indicating a pattern of severe, high speed crashes. The fatal crash occurred late on a Saturday night; it was dark and the pavement was wet. The eastbound vehicle (car) failed to yield to the southbound vehicle (motorcycle). Alcohol was a factor for both drivers; the driver of the motorcycle was the fatality.

The rear end crashes mostly occurred from vehicles on SR 3 that were unable to slow down for vehicles slowing in front of them to make a turn onto Plumb Road. Two of the three left turn crashes also occurred

from vehicles on SR 3 that failed to successfully turn left in front of oncoming traffic. A combination of high traffic volumes and high speeds appear to be contributing to the angle, rear end and left turn crashes. In addition, 39% of the crashes occurred in wet or snowy conditions. After further analysis, no crash pattern emerged related to adverse weather conditions, but these conditions can contribute to already identified crash problems in the project area.

Most crashes occurred during the day on dry pavement under no adverse weather conditions, so weather, pavement condition and lighting do not appear to be a factor in the crashes. The crashes peaked during the morning, noon, and evening rush hours when more traffic is traveling these roadways thus making traversing the intersection more challenging. An additional peak did occur late at night in dark conditions, including the fatality, of which the driver was driving under the influence of alcohol.

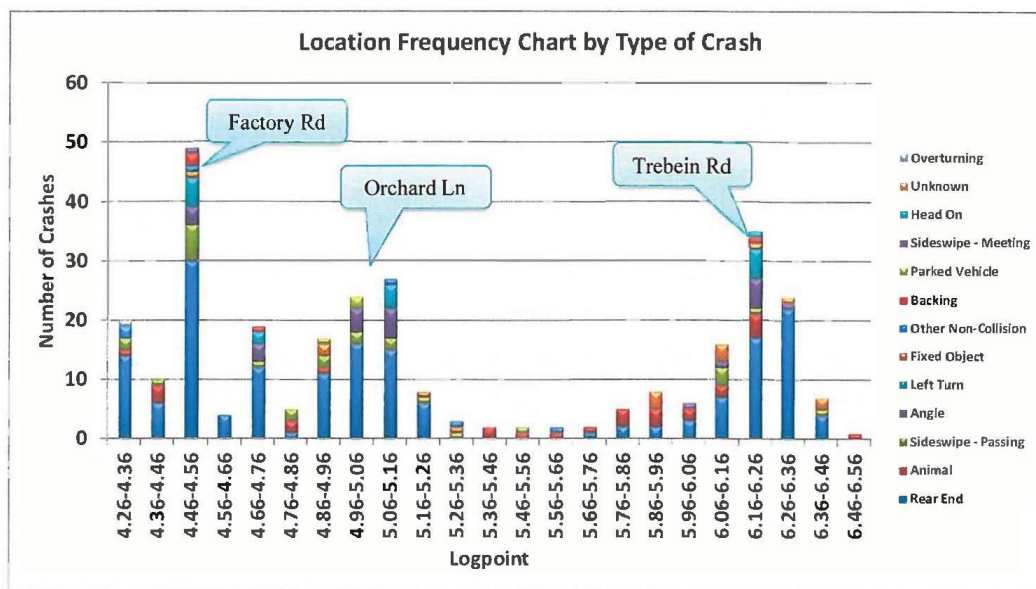
Example 3

From 2009-2011, 296 crashes occurred within the study area. In 2009 there were 101 crashes; in 2010 there were 97 crashes; and in 2011 there were 98 crashes. Of the total crashes, 30% resulted in injury and there was 1 fatality. The most prominent type of crashes were rear end crashes with 58% followed by animal crashes with 9%, sideswipe passing crashes with 9%, and angle crashes with 7%. Approximately 31% of the crashes occurred in wet, snow or ice conditions. The highest contributing factor to the crashes was following too closely. Please see Appendix B for the crash analysis and Appendix C for the crash diagrams. Note that only 2011 crashes were plotted in the crash diagrams.

Wednesdays had the most crashes with 20%, followed by Thursday's with 17%, Saturday's with 15% and Friday's with 14%. Most of the crashes occurred in the am peak between 6am-9am (22%) and in the pm peak between 3pm-6pm (33%). The light condition was daylight for 75% of the crashes and dark-no lights for 16% of the crashes. The month with the highest number of crashes was October (13%) followed by May (11%) but they were all pretty equal.

Half (50%) of the crashes involved drivers who were westbound on US-35 and 43% of the crashes involved drivers who were eastbound on US-35. The estimated speed was 20mph and under for 33% of the crashes even though the posted speed limit is 55mph.

The figure below shows the breakdown of where crashes occurred (logpoints) from 2009-2011 and the type of crash that occurred. It shows that most of the crashes happened at signalized intersections.



4.7.2 Collision Diagram(s)

A collision diagram is a schematic drawing that has been compiled from a series of individual crash reports relative to a specific location (intersection or section), which shows the direction the vehicles traveled prior to contact, and pedestrians whose presence contributed to a collision. A minimum of three years of the latest crash data should be used to draft the collision diagram. See *Figures 9a and 9b* for sample intersection collision diagrams and *Figure 10* for a roadway section collision diagram.

The following information should be included in the collision diagram:

1. Title box with county, route, section, Priority List and Rank (if applicable), and crash data time period (e.g., 2010-2012). The title box should also have the initials of the person it was drawn by and the date it was completed.
2. Schematic of location: Each approach should be labeled and the north arrow shown.
3. Each crash should include the following information as a minimum: date, time and pavement conditions. This information is typically shown on the line for the driver at fault. Any other pertinent information about the accident, or driver at fault, should also be shown (e.g., injury, intoxicated, ran STOP sign or red light, etc.).
4. Legend key to denote all symbols used must be included in the collision diagram.
5. When possible, aerial imagery should be used as the basemap of the collision diagrams. It provides easy reference points and allows improvements to be easily connected to the crash patterns at the site.

4.7.3 Crash Summary Narrative

4.7.4 Site Diagnosis and Identification of Potential Countermeasures

The Crash Data and Analysis section of the report should include a summary of the site diagnosis (Step 1) and results of the determination of the potential for site safety improvements (Step 2). Summary results of the potential for safety improvement which can be obtained from the report output of the ECAT Tool, see Figure 11 should be summarized in the safety study report narrative. Detailed output from the ECAT (print of ECAT Report Tab) should be included within the document appendices.

It is appropriate to include observations on potential contributing factors, notable crash patterns, and geometric deficiencies relating to the safety issues that have been identified through review of existing crash patterns, roadway conditions, traffic control, traffic volumes, vehicle speeds, etc. or through the evaluation of the potential for site safety improvements and comparison of the expected crash performance of the site relative to the predicted performance of peer sites.

Example 1

The possible causes or deficiencies in the intersection were identified through a detailed analysis of the crash patterns, roadway conditions, existing traffic control, traffic volumes and traffic speeds. The calculated expected crash frequency indicated a need for further investigation, and possible implementation of traffic control measures.

We have identified possible safety items at the intersection as follows:

- *Poor lane utilization and excessive queuing that occur EB in the driving lane causes secondary crashes at the adjacent private drives west of the intersection with cars pulling through the queue.*
- *The left hand turn lane on the northbound approach gets backed up due to a high number of vehicles waiting to turn left at the intersection. This prohibits people that want to turn right from accessing the right hand turn lane. Vehicles were observed using the right shoulder, to go around vehicles waiting on the left turn, to access the right turn lane. Vehicles that were backed up in the left turn lane that wanted*

Figure 9a: Intersection Collision Diagram

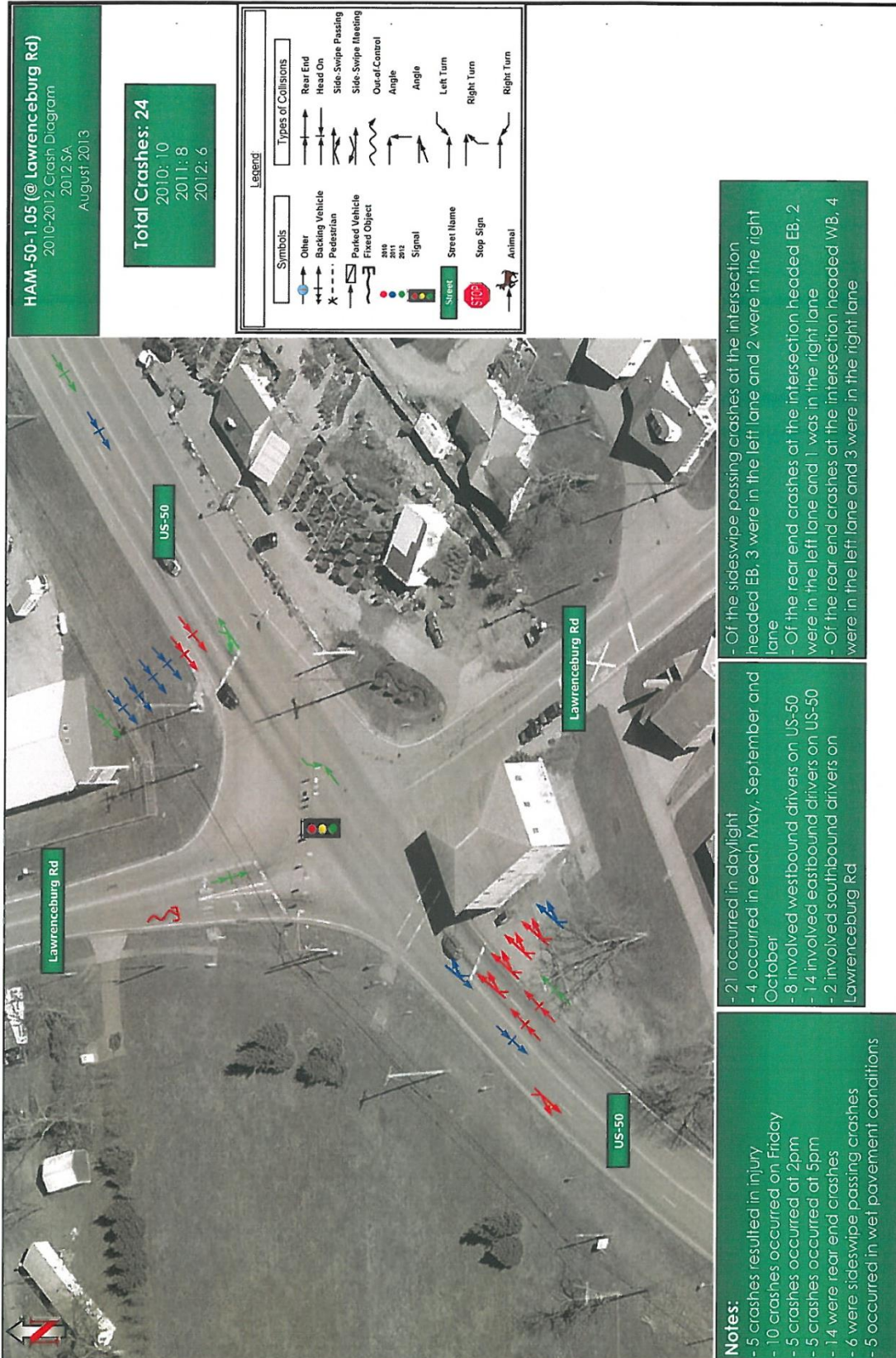


Figure 9b: Intersection Collision Diagram Example 2

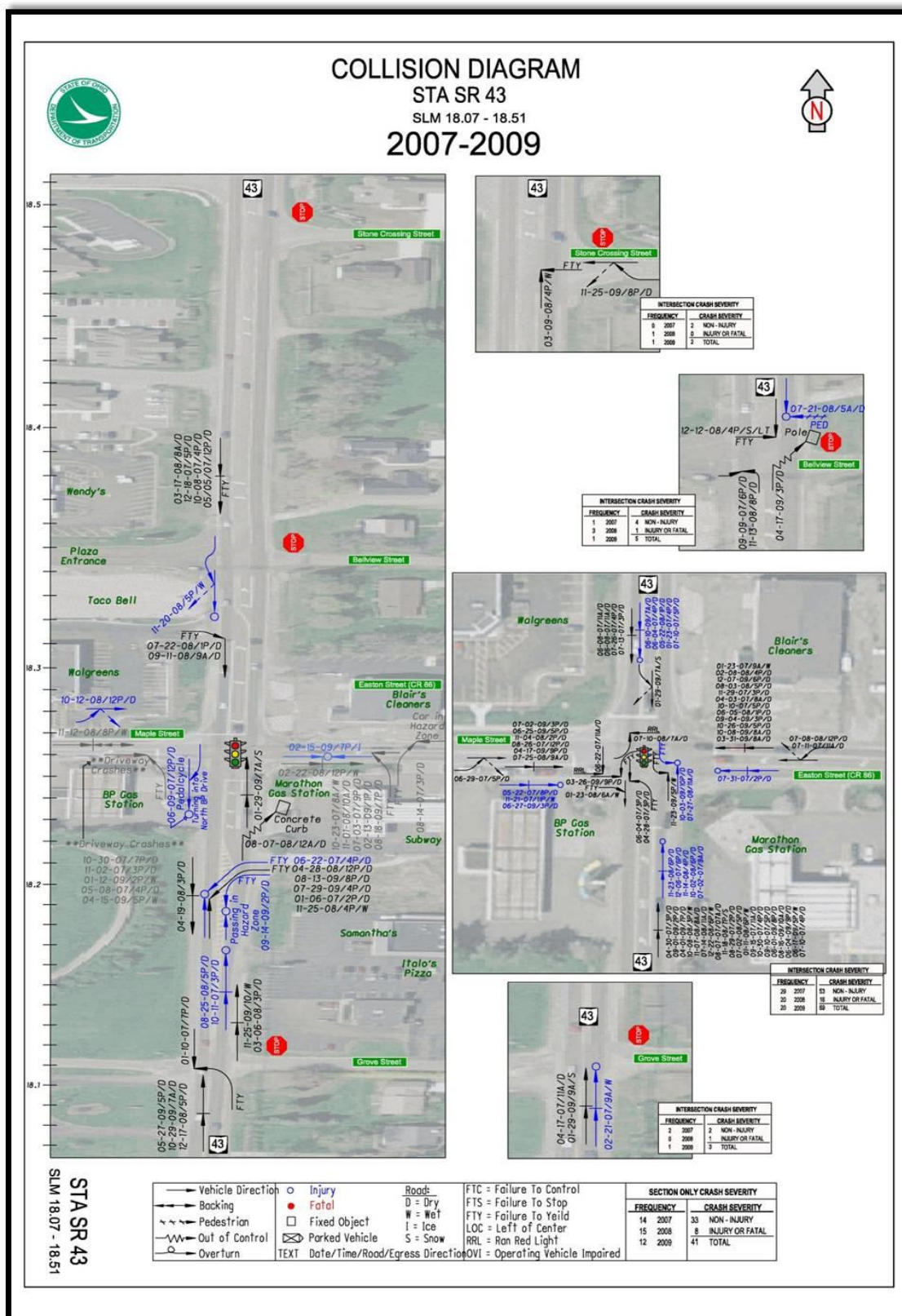


Figure 10: Roadway Section Collision Diagram Example

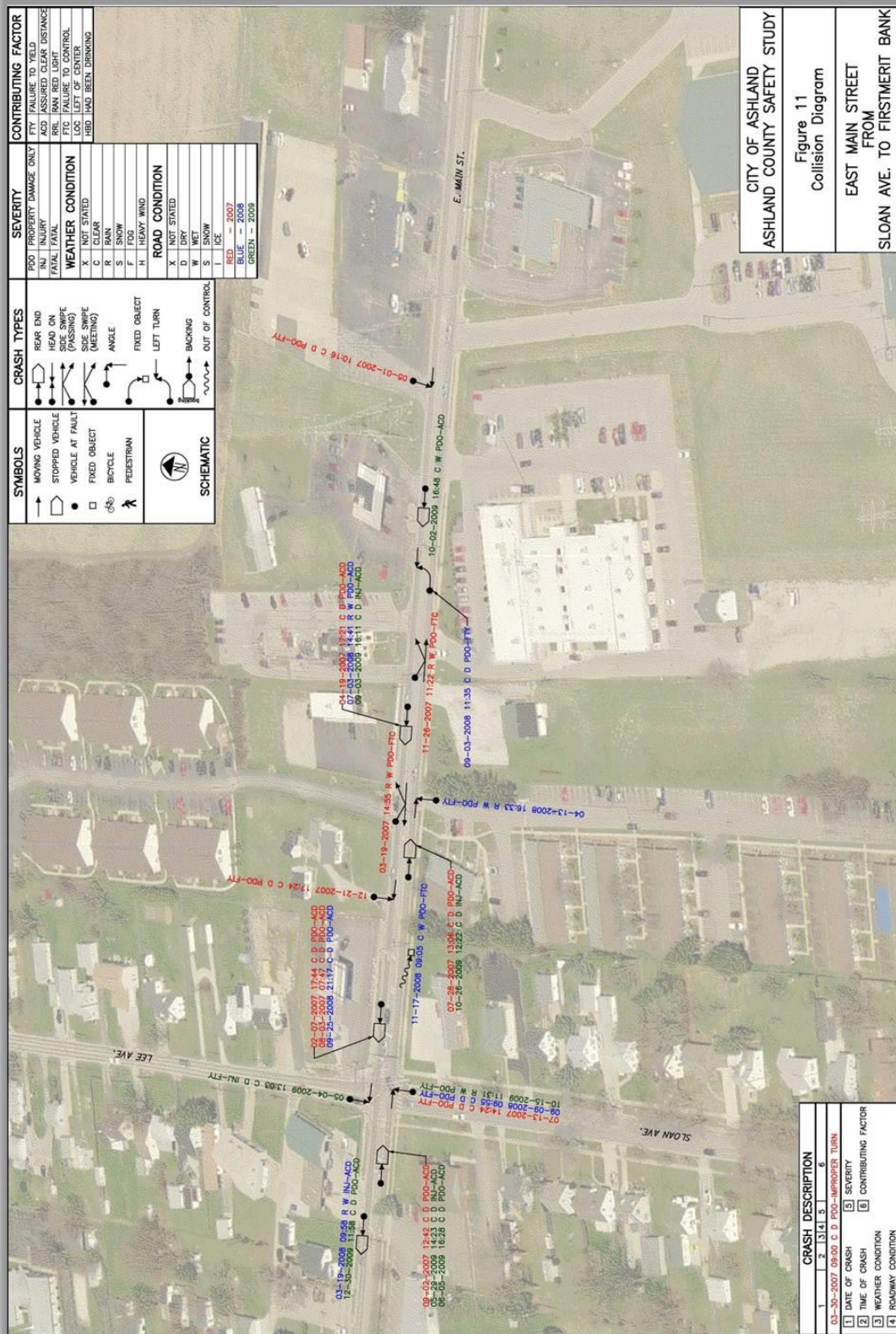
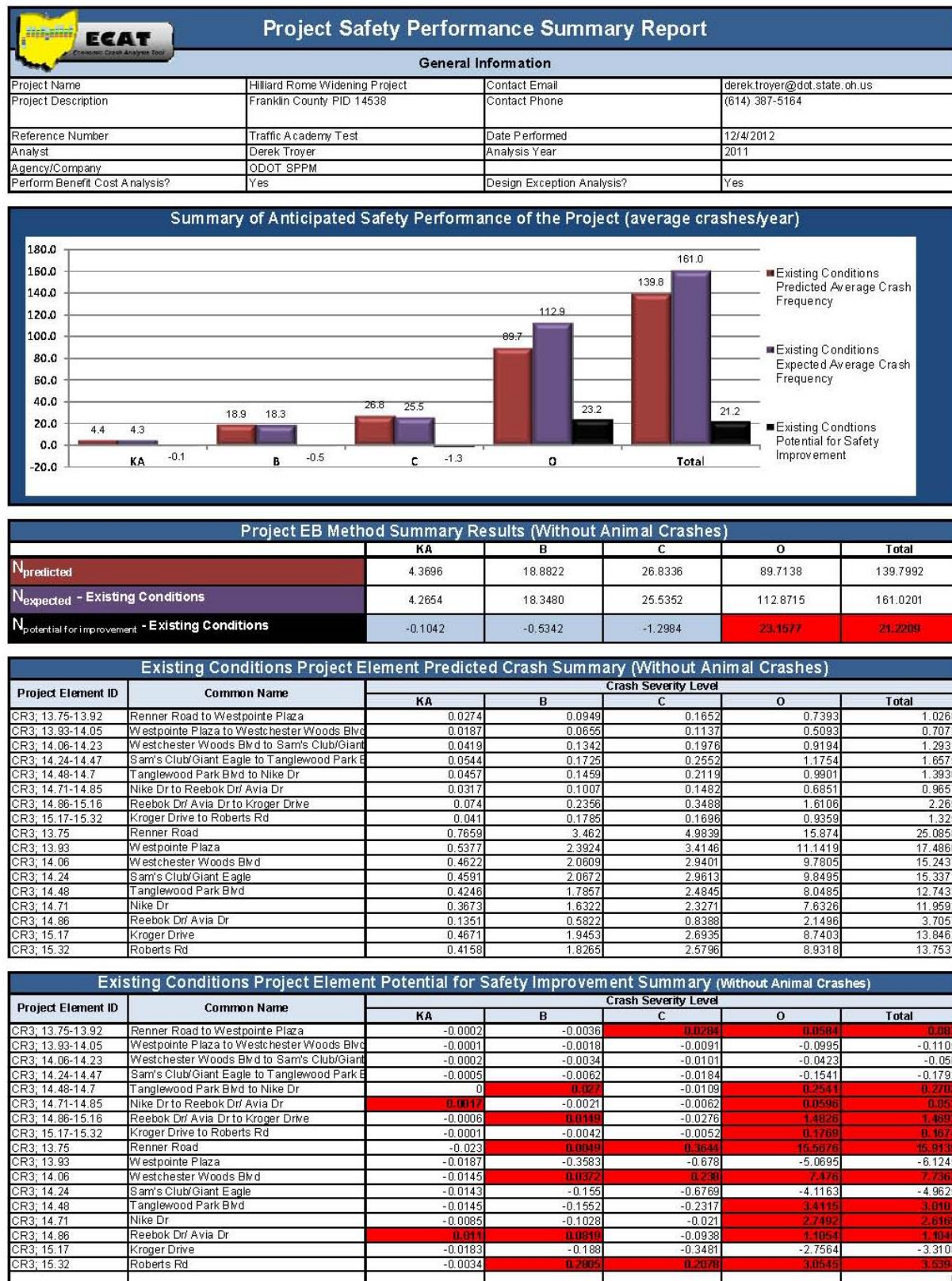


Figure 11: ECAT Potential for Safety Improvement Existing - Example

to turn left onto Coral Rd., which is very close to the intersection, were observed going north in the southbound lane trying to beat southbound traffic and quickly turn onto Coral Rd.

- *Coral Rd. intersects SR 43 just to the south of the intersection. Vehicles traveling east on Coral Rd. are prohibited from making a left turn (north) onto SR 43. Several vehicles ignored the prohibited left turn sign and turned left.*

Example 2

State Route 164 intersects SR 558 as a two way stop-controlled intersection with stop control for the SR 558 approaches. There are no exclusive turn lanes at the intersection. Field observations suggest a high level of truck traffic on both study roadways. In the northwest and southeast quadrants of the intersection, tread marks outside of the paved surface suggest that southbound and northbound right turning radii are insufficient.

Example 3

The results of the existing conditions crash analysis indicate a potential for site safety improvement of 8.2 crashes per year and the majority of the expected excess crashes (5.9 crashes/year) are expected to be rear-end. This indicates that the site is experiencing a higher overall frequency of crashes than would be expected for similar sites and suggests that the priority crash type to address and mitigate should be rear-end. Actual site data also indicates that there is a pattern of angle crashes occurring when northbound vehicles strike vehicles turning left from southbound to westbound. Based on this information and information obtained in a field review of the site several observations were made about the operation of the intersection:

- *Congestion in combination with insufficient signal timing may make it difficult for vehicles to clear intersection within the allotted clearance interval*
- *There are an insufficient number of gaps in the northbound traffic stream for southbound traffic to cross during the permissive left signal phase likely contributing to the observed angle crash pattern at this location*
- *There is limited visibility of the signal heads on the northbound approach to the intersection forcing vehicles to make sudden stops once the signal becomes visible and likely leading to the pattern of rear end crashes on the northbound approach.*
- *A comparison of the expected number of night time crashes for the site to the predicted crash frequency for peer sites indicates that this site is experiencing more night time crashes than would generally be predicted for this type of intersection.*

This section should identify and describe the (potential) countermeasures identified for consideration based on the results of the ECAT analysis (potential for safety improvement) and site diagnosis and document the justification for evaluation of these countermeasures as potential solutions to the site safety issues.

The cost of a countermeasure is the cost of improvement through force account or contract work, and should be calculated for every potential countermeasure. The estimated improvement costs include those expected costs required for implementation and maintenance of the countermeasure of the estimated safety countermeasure based on an estimate.

4.7.5 Design Evaluation (if applicable)

In addition to traffic related issues that influence the recommendations of the safety study, there may be non-traffic design issues that may have an impact on project scope, schedule and cost. When developing the recommended solutions for a safety study, these design issues should be evaluated at a conceptual level to determine their impacts on the project.

The Design Evaluation section of the safety study should summarize any design issues which should be considered in future plan development activities or that are likely to have a significant impact on project cost.

Example 1

Using 12' lanes and 8' graded shoulders may have an impact on a possible wetland on the south side of S.R. 56 approximately 0.5 miles west of Shaker Road. The area should be evaluated to determine if a wetland is present. If this area is determined to be a wetland, the designer should investigate minimizing impacts by widening to the north.

Example 2

Due to the number of residential homes located in close proximity to the roadway on both sides of S.R. 13, it is desired to use a closed drainage system to minimize right-of-way impacts caused by widening the roadway. If significant impacts are encountered using a closed drainage system and full graded shoulder criteria, the designer should evaluate the use of a reduced graded shoulder width and obtaining a design exception.

Example 3

The existing bridge cannot be utilized for part width construction due to the configuration of the existing substructure. In order to facilitate maintenance of traffic, the proposed alignment should be established such that it does not fall within the limits of the existing bridge. In this way, the existing bridge can be used to maintain traffic during construction of the proposed bridge.

4.7.6 Proposed Countermeasure Evaluation

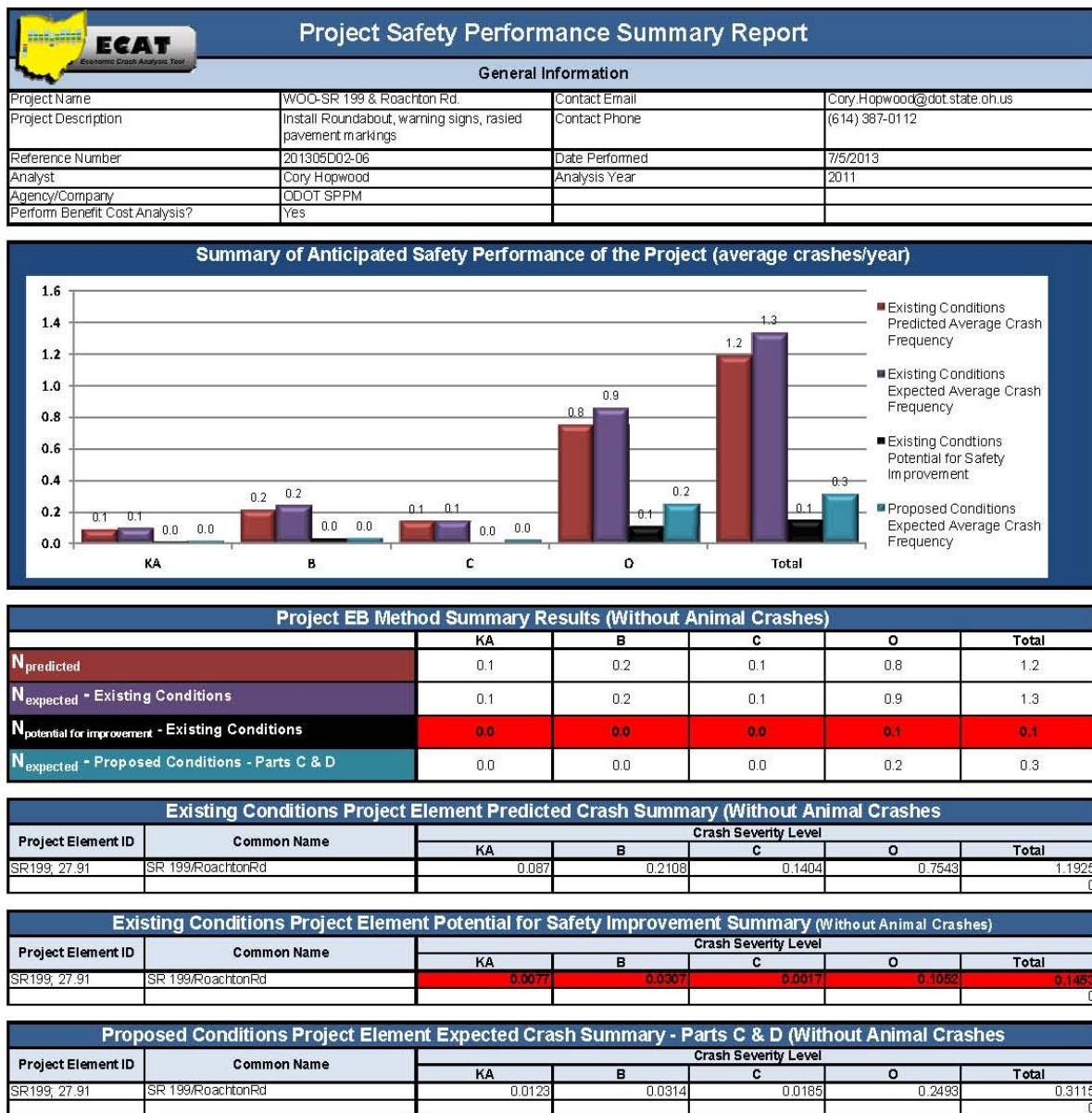
This section of the report should include a summary of the results of the proposed countermeasure evaluation. Crash analysis results including the predicted and expected crash performance of the existing site conditions and relative potential for safety improvement as well as the calculation of the expected crash frequencies of the proposed countermeasures can be obtained from the report output of the ECAT Tool, upon completion of the countermeasure evaluation step (Figure 12). It may be necessary to perform more than one set of analyses using separate ECAT spreadsheets if multiple independent countermeasures or combinations of countermeasures are being evaluated. A summary of the results of the proposed countermeasure evaluation(s) should be presented in this section of the safety study report narrative. Detailed output (print of ECAT Report Tab) from the ECAT can be included within the document appendices. A copy of each ECAT spreadsheet used to perform the analysis (existing and proposed conditions) should be provided to ODOT with the draft safety study document for review.

4.7.7 Conclusions

The conclusions should summarize all countermeasures evaluated and provide comparison of the site safety performance with the proposed countermeasure or countermeasures to the predicted performance of peer sites and the expected performance of the actual site. A summary of the crash analysis results for the predicted and expected crash performance of the existing site conditions and the expected crash frequencies of the proposed countermeasures can be obtained from the report output of the ECAT Tool (Figure 12). The conclusions should include a discussion of the potential for safety improvement and how each countermeasure or package of countermeasures performs in terms of reducing crash frequency at the site. This section should also identify and explain any countermeasures that dismissed from consideration.

4.8 Summary of Supplemental Traffic Studies

This section should include a summary of the results of any other transportation analysis or supplemental traffic studies conducted per Step 3 of the safety study process. A copy of the full documentation of each supplemental study should be included in the Appendices.

Figure 12: ECAT Potential for Safety Improvement Proposed - Example

4.9 Recommendations and Prioritization

4.9.1 Countermeasure Recommendations and Implementation Plan

A recommended countermeasure is a highway safety treatment designed to address a safety concern and/or potential for safety improvement at a given site. The final countermeasure recommendations included in the safety study should be based upon the safety enhancements identified as appropriate for the location and as documented through the crash analysis and proposed countermeasure evaluation process.

Many factors need to be considered when developing countermeasures and recommendations. For example, they may include engineering, enforcement, driver education or a combination of factors. The recommendations should be based on knowledge of the effectiveness of the improvement being recommended in similar situations and should consider the needs of all users. Improvements should be

based upon the traffic and site conditions. A combination of improvements may be the best practical countermeasure for a location. All practical improvements, including “do nothing,” should be identified and considered and analyzed for safety so that no feasible alternative is overlooked.

The countermeasure evaluation and countermeasure costs for the proposed countermeasure(s) should be used to inform the selection and prioritization of recommended countermeasures through a benefit/cost analysis process using the ECAT. The benefit/cost ratio is a comparison of the estimated net present value of safety benefits to the estimated project cost for the proposed safety countermeasure or combination of safety countermeasures. The net present value of the countermeasure is the expected dollar value of safety benefits in terms of crashes prevented. The cost/benefit ratio analysis establishes the benefits expected to be obtained by an improvement and should be included for every recommended alternative. A benefit-cost ratio greater than 1.0 is the desired condition and means that the present value of the safety benefits exceeds the present value of the construction. Where the benefit cost ratio is less than 1.0, the present value of the safety benefits are less than the present value of construction costs. This is not preferred and when encountered, indicates that other alternative countermeasures should be considered and evaluated.

The safety study should include recommendations of a countermeasure or countermeasures based on the results of the crash analysis and economic (cost-benefit) analysis. The countermeasure evaluation calculations and benefit/cost analysis is required for any safety funding application submitted for the recommended countermeasures. Countermeasure(s) recommended by a safety study may result in a project that follows the **Project Development Process (PDP)**. Depending on the scope of work, these projects may result in work that only requires a Path 1 level of work compared to the more complex Path 2-5 level projects. The recommendations should indicate priority of implementation, a discussion on the implementation approach and also briefly summarize the scope of work expected Project Development Process Path for each proposed countermeasure. See Attachment B for an example of summary output and countermeasure recommendations/implementation plan.

4.9.2 Proposed Condition Diagrams

Proposed condition diagrams should be prepared to detail the proposed countermeasure or countermeasure treatments recommended for funding and implementation (Figure 14a and Figure 14b).

4.10 Appendices (If Completed or Authorized)

The Appendix will include related material such as that shown below to further document and enhance the quality of the safety study. The references shown for the different topics are just a guide and are not meant to be the only source. These topics are covered by many traffic engineering manuals, including ITE handbooks, and those should be used as a source for reference.

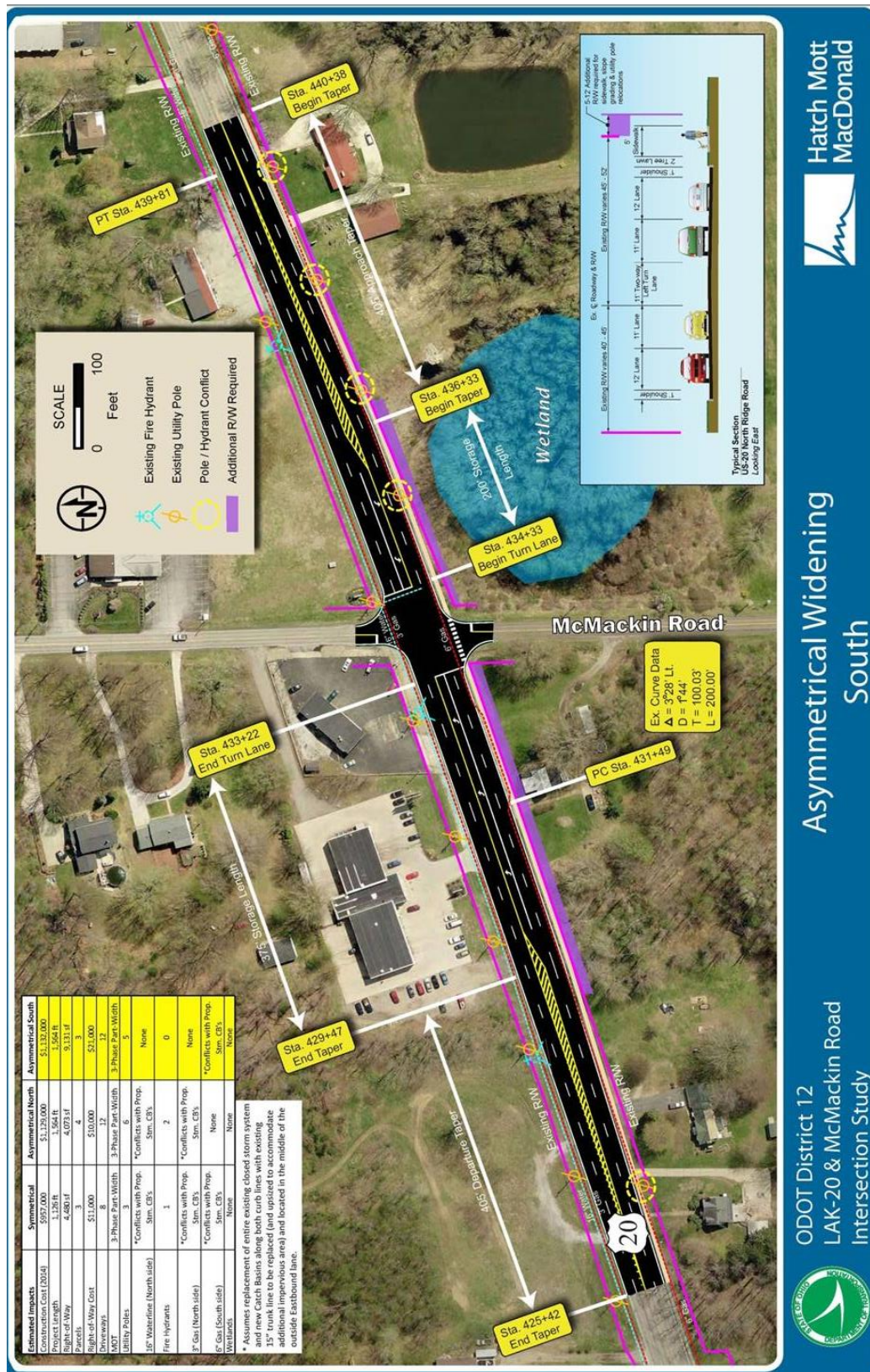
1. Traffic Volume Count: Required.

This is discussed elsewhere in Chapter 12 of the TEM and in Chapter 2 of the ITE Manual of Transportation Engineering Studies.

2. Crash Summaries: Required.
3. ECAT tool analysis results in report format: Required.
4. Aerial and Other Photos of the Location: If applicable.
5. Field Review Notes: If applicable.

See the Field Review Forms developed as part of the ODOT research report Rural Highway Safety Advisor (RITA).

Figure 14a: Proposed Conditions Diagram Example 1



6. Traffic Speed Studies: If applicable.

This is discussed Chapter 12 of the TEM and in Chapter 3 of the ITE Manual of Transportation Engineering Studies.

7. Traffic Signal Warrants: If applicable.

See TEM Chapter 4 and OMUTCD Part 4 for further information about traffic signal warrants.

8. Other Traffic Studies and Analyses: If applicable.

See the TEM Chapter 12 and the ITE Manual of Transportation Engineering Studies for information about other traffic studies and analyses that may be applicable. Also see OMUTCD Section 1A.11 and TEM Chapter 1 for information on additional studies that may performed to supplement data and support the analysis performed in the safety study.

Abbreviated Safety Study Format and Contents

Abbreviated safety studies are typically performed internally by ODOT staff or by Task Order. Abbreviated studies are required to update the status of any priority list locations that have remained in the top 50 ranked sites for the respective study site type despite previous study and countermeasure implementation and for which at least three years have passed since any proposed improvement recommended by previous study has been in place. Abbreviated studies may also be required by ODOT when funding is being requested for additional (future) phases of implementation for any site to which funding has previously been allocated within the past 3-5 years.

5.1 Table of Contents

Abbreviated safety study reports shall have a Table of Contents (see Figure 15).

5.2 Title Page

The report shall have a title page similar to the format for the full study title page with the exception that the report should be noted as 'Abbreviated'. It should show the **District, County**, Route, Section, Safety Analyst Number (#), Safety Annual Work Program (SAWP) Year, study completion date, and a location map.

5.3 Overview

5.3.1 Existing Conditions

This section of the report is used to identify the location being studied (County/City/Township, Route, and Section), type of facility (Functional Classification, number and direction of lanes) existing traffic control, history of safety problems or crashes, and reason for the study. If applicable, information summarizing previous improvements implemented to mitigate crashes should be documented.

When an abbreviated study is being prepared for a previously studied location reference can be made to previous reports and documentation as long as copies of the referenced documents are included as appendices to the abbreviated study. The abbreviated study should include a summary of existing conditions information contained in these other documents and document any new conditions that have been identified and aren't reflected in the attached documentation.

Where conditions have changed, updated physical condition diagrams are required to document the current state of existing conditions.

5.3.2 Crash Data and Analysis

The crash data section in an abbreviated study should be similar to the crash data and analysis of a full study. All crash analysis should be updated to reflect the most current three years of data and analysis performed for existing and proposed conditions. The existing site condition analysis should include countermeasures completed and in place.

5.3.3 Probable Causes and Potential Countermeasures

The index of countermeasures contained in the ECAT may be used to determine appropriate countermeasures to address both new and previously identified safety issues at the site.

Where site conditions (geometry and traffic volume) have remained relatively unchanged, the identification and evaluation of proposed countermeasures should consider the results of previous studies and evaluate only the new treatments otherwise not presented and evaluated in earlier studies.

5.4 Implementation Plan

The recommended implementation plan to address a location for which an abbreviated study is being performed should consider countermeasures complete and in place, countermeasures proposed and evaluated in previous studies, and any new countermeasures identified as a result of updated data and analysis.

Countermeasures considered for implementation should include a cost estimation and be classified in terms of implementation timeframes as follows:

- Short-Term Countermeasures (Under 1 year)
- Medium-Term Countermeasures (1 to 5 years)
- Long-Term Countermeasures (Over 5 years)

A comparative summary of relative cost and cost-benefit value for all proposed solutions should be presented and used to develop the approach to implementation (implementation) for countermeasures recommended for funding and implementation.

5.5 Appendices (If Completed or Required)

See Section 3.3 Safety Study Process, Step 3 – Perform Relevant Traffic Studies and Section 4.10, Full Safety Study Format and Contents, Appendices for information on resources for conducting additional studies and/or related material that should be included in the Appendices to further document and enhance the quality of the safety study.

Figure 15: Abbreviated Study Table of Contents

Table of Contents

- I. Title Page
- II. Overview
 - A. Existing Conditions
 - B. Crash Data and Analysis
 - C. Probable Causes and Potential Countermeasures
- III. Implementation Plan
- IV. Appendices

Safety Funding Application – Required Calculations

6.1 Background

The safety funding application is due to Central Office annually by **April 30** and **September 30** of each year. Local sponsors should coordinate applications with their local district office at least six weeks in advance of this deadline. Every application and supporting documentation must be reviewed and approved by the district prior to submission to Central Office. This application and supporting documentation will be used by the Safety Program Committee to set the safety program priorities.

Beginning with the April 2014 round of funding applications, ODOT will require the use of the new analysis methods and safety study procedure documented in these guidelines.

6.2 Safety Application Contents

The safety funding application is submitted for projects that are listed on the ODOT District Office Safety Annual Work Plan or on priority lists developed by local governments. Projects which have fewer than ten crashes in the most recent three-year period and an annual crash rate less than 1.0 crashes / MVM are typically not eligible. Projects which cost less than \$50,000 are also not typically eligible. The following items should be included in the safety application:

1. Brief Project Description – Including CO-RT-SEC, District, PID if assigned
2. Summary of Problem Statement
3. Summary of Recommended Countermeasures
4. Project Priority (Rank, LPA priority)
5. Project Development Status
6. Crash data points
7. Copy of the Safety Engineering Study
8. Traffic Volume Data
9. Project Location Map
10. Photographs of the Project Site
11. Economic Analysis
12. Estimated Cost by phase and funding source
13. Affirmative signatures from a majority of the DSRT members
14. Name of a contact person
15. Project sponsoring agency
16. Project schedule

Sample HSM Calculation

Rural 3-Leg Stop Controlled Intersection Example

Input Data:

AADT Major Street	19,900
AADT Minor Street	1,070
Left-turn lane on approaches without stop control	None
Right-turn lane on approaches without stop control	None
Lighting	Not Present
Skew (absolute value of deviation from 90 degrees)	35°
Observed Crash Data (3-year total)	
Fatal Crashes	0
Serious Injury Crashes	1
All Injury Crashes	9
PDO Crashes	27
Calibration Factor:	1.00

Safety Performance Function (SPF) Calculation:

HSM Equation 10-8

$$N_{spf3ST} = \exp[-9.86 + 0.79 \times \ln(AADT_{maj}) + 0.49 \times \ln(AADT_{min})]$$

$$N_{spf3ST} = \exp[-9.86 + 0.79 \times \ln(19,900) + 0.49 \times \ln(1,070)]$$

$$N_{spf3ST} = 3.9660$$

Part C Crash Modification Factor (CMF) Calculations

Left-turn lane on approaches without stop control:

Site conditions are the same as base conditions. Therefore, no calculation required

Right-turn lane on approaches without stop control:

Site conditions are the same as base conditions. Therefore, no calculation required

Lighting:

Site conditions are the same as base conditions. Therefore, no calculation required

Skew Angle:

HSM Equation 10-22

$$CMF_{1i} = e^{(0.004 \times skew)}$$

$$CMF_{1i} = e^{(0.004 \times 35^\circ)}$$

$$CMF_{1i} = 1.1503$$

Calculate the Predicted Average Crash Frequency

$$N_{predicted} = N_{spf} \times (CMF_1 \times \dots \times CMF_i) \times C$$

$$N_{predicted} = N_{spf3ST} \times CMF_{1i} \times C$$

$$N_{predicted} = 3.9658 \times 1.1503 \times 1.0$$

$$N_{predicted} = 4.5619 \text{ total crashes per year}$$

Calculate the weighting Factor (w)

Find the k value for rural 3-leg stop controlled intersections

$$k = 0.54$$

Equation A-5

$$w = \frac{1}{[1 + k \times (\sum N_{predicted})]}$$

$$w = \frac{1}{[1 + 0.54 \times 4.5619]}$$

$$w = 0.2887$$

Calculate the Expected Average Crash Frequency

Equation A-4

$$N_{expected} = w \times N_{predicted} + (1 - w) \times N_{observed}$$

$$N_{expected} = 0.2887 \times 4.5619 + (1 - 0.2887) \times \frac{(9 + 27)}{3 \text{ years}}$$

$$N_{expected} = 9.8526 \text{ crashes per year}$$

Calculate the Expected Excess Average Crash Frequency (Potential for Safety Improvement)

$$N_{expected \text{ excess}} = N_{expected} - N_{predicted}$$

$$N_{expected \text{ excess}} = 9.8526 - 4.5619$$

$$N_{expected \text{ excess}} = 5.2907 \text{ crashes per year}$$

Summary

$$N_{predicted} = 4.5619 \text{ crashes per year}$$

$$N_{expected} = 9.8526 \text{ crashes per year}$$

$$N_{expected \text{ excess (PSI)}} = 5.2907 \text{ crashes per year}$$

Definitions

Base Conditions- the base geometric conditions that the SPFs are based on

Calibration Factor- a factor to adjust crash frequency estimate produced from a safety prediction procedure to approximate local conditions

Countermeasure- a roadway-based strategy intended to reduce the crash frequency or severity, or both at a site

Comprehensive Crash Cost- The cost of each crash by either crash type or severity that includes the human capital costs in addition to non-monetary costs related to the reduction in the quality of life in order to capture a more accurate level of the burden of injury.

Crash Frequency- the basic measure of crashes in the HSM, number of crashes occurring at a particular site, facility, or network per year (expressed for a location/site or per mile depending on the context)

Crash Modification Factor (CMF)- value which quantifies the change in crash frequency at a site as a result of implementing a specific countermeasure or treatment. It can be single value or function and may apply to all crashes or specific crash type(s).

Crash Severity-the level of injury or property damage due to a crash, commonly divided into categories based on the KABCO scale.

District Safety Review Team (DSRT) develops and adopts a Safety Annual Work Plan, reviews safety studies for locations included in the work plan, and recommends countermeasures. The DSRT also reviews local safety studies and funding requests. The DSRT shall have a minimum of the following ODOT multi-disciplinary representatives or equivalents for the district, including:

- Planning and Engineering Administrator
- Highway Management Administrator
- Design Engineer
- Planning Manager
- Traffic Engineer

The DSRT should also consult with the District Real Estate Administrator and Environmental Coordinator to ensure that safety projects are properly scoped to address real estate and environmental issues that can significantly increase costs and cause delays.

The District Deputy Director shall appoint one ODOT DSRT member as chairperson to coordinate and steer the team's efforts. Each District is also required to invite the Highway Safety Improvement Program Manager and a representative from Federal Highway Administration. The local Ohio State Highway Patrol, local law enforcement and Metropolitan Planning Organization may also be invited. LPA representatives shall be invited when the DSRT is reviewing an LPA safety study. Only ODOT representatives may be voting members.

Economic Analysis- This analysis will be used to determine a project's benefits and costs for the purpose of assisting in determining the project's eligibility for funding and for prioritizing multiple projects/alternatives.

Empirical Bayes' (EB) Method- combines actual site crash history with predicted average crash frequency by weighting the values based on the strength of the model and the overdispersion parameter to obtain the expected crash frequency

Expected Average Crash Frequency- the estimate of long-term expected average crash frequency of a site, facility, or network under a given set of geometric conditions and traffic volumes (AADT) in a given period of years.

Expected Excess Crashes- the difference between the expected average crash frequency and the predicted average crash frequency; estimates how much the long-term crash frequency could be reduced at a particular site. This is also known as the ‘potential for safety improvement.’

Highway Safety Improvement Program Committee- A multi-disciplinary committee at ODOT Central Office representing the Highway Safety Improvement Program, Roadway Engineering, Office of Traffic, and other active safety participants that reviews all safety project applications and documentation to select projects that will be funded through the Highway Safety Improvement Program.

Highway Safety Improvement Program Manager- The individual responsible for administering the statewide policies and program selection criteria for the purpose of developing a multi-year program of priority projects. The program manager ensures the project delivery adheres to the schedule and maintains a fiscally balanced program.

Highway Safety Improvement Program Prioritized Location Listing- The Office of Systems Planning and Program Management will annually prepare and distribute to the Districts a prioritized listing of locations on the state highway system for the Highway Safety Improvement Program. The prioritized listing will utilize criteria established by ODOT and crash data provided by the Ohio Department of Public Safety.

Homogenous Roadway Segment- a portion of road that has a consistent roadway cross-section and is defined by two endpoints

Human Capital Crash Costs- The cost of each crash by either crash type or severity that includes monetary losses associated with medical care, emergency services, property damage, and lost productivity.

Intersection- general area where two or more roadways or highways meet, including the roadway, and roadside facilities for pedestrian and bicycle movements within the area

KABCO- an injury scale developed by the National Safety Council to measure the observed injury severity for any person involved as determined by law enforcement at the scene of the crash. Includes K, A, B, C, and O severity levels, highest to lowest.

Local Public Agency (LPA)- LPA’s can include any other state agency, local political subdivision, board, commission, or other governmental entity identified under paragraph C of Section 5501.03 of the Ohio Revised Code as being eligible for assuming administrative responsibilities for ODOT improvement projects.

Mandatory function- clearly defined tasks or responsibilities entailing little personal judgment (e.g. highway maintenance activities)

Major Street- the higher volume street at a stop-controlled or signalized intersection

Minor Street- the lower volume street controlled by stop signs at a two-way or four-way stop-controlled intersection or the lower volume street at a signalized intersection

Negligence- a failure to do what an ordinary, reasonably prudent person would do under similar circumstances; a failure to use reasonable care in dealing with others

Nominal Safety- examined in reference to compliance with standards, warrants, guidelines, and sanctioned design procedures

Observed crash frequency- The actual number of crashes that have occurred at a particular site, facility, or network per year that have been investigated and reported by law enforcement agencies.

Offset- lateral distance from edge of traveled way to a roadside object or feature

Overdispersion Parameter (k)- the measure of the model’s (SPF) strength or how widely the crash counts are distributed around the estimated mean

Potential For Safety Improvement (PSI)- see *Expected Excess Crashes*

Predicted Average Crash Frequency- the estimate of long-term average crash frequency which is forecast to occur at a site using a predictive model found in Part C of the HSM. The predictive models in the HSM involve the use of regression models, known as Safety Performance Functions, in combination with Crash Modification Factors and calibration factors to adjust the model to site-specific and local conditions.

Predictive Method- the methodology in Part C of the manual used to estimate the 'expected average crash frequency' of a site, facility, or roadway under given geometric conditions, traffic volumes, and period of time.

Roadway Segment— see *Homogenous Roadway Segment*

Safety Annual Work Plan (SAWP)- Each year ODOT will study the designated number of priority locations produced by AASHTOWare Safety Analyst and reviewed and accepted by the districts. These locations shall consist of a combination of rural and urban locations as well as freeway, non-freeway and at-grade intersection locations. A priority location will be studied only once in a three-year period, even though it will likely continue to appear in the priority list. This will increase the number of safety locations reviewed across the state.

The Districts may also include other locations they deem appropriate to include in their review of the District's highway safety needs. Local priority projects submitted by an LPA and approved by the DSRT must also be incorporated into the District Safety Annual Work Plan tracking system.

Safety Performance Function (SPF)- mathematical expression used to estimate the expected average crash frequency for a base condition; product of a statistical modeling process.

Safety Study- A Safety Study involves analysis of roadway, traffic and crash-related data to determine the probable cause of an identified crash pattern at an intersection or highway section. The safety study also provides alternative countermeasures meant to mitigate predominate crash pattern(s).

Segment Length- center of intersection to center of intersection

Site- project location consisting of, but not limited to, intersections, ramps, interchanges, at-grade rail crossings, roadway segments, etc.

Substantive Safety- the expected or actual crash frequency and severity for a highway or roadway

Tort- a civil wrong or injury